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ABSTRACT

This theme issue features five articles profiling Indiana University faculty whose work on various campuses continues to broaden and advance knowledge about cognitive science. The articles in the journal are: "A Matter of Time" (Karen Grooms) which discusses the work of Robert F. Port; "Perceiving as a Complex System" (Tom Tierney) which profiles Linda Smith and her research; "The Mind/Body Problem Revisited" (Renee Despres) which considers the interests of Timothy van Gelder; "Face Perception" (Roberta Neiger) which profiles Jim Townsend and his research; and "The Power of Abstraction in Problem Solving" (Anne Kolaczyk and Ed Kolaczyk) which discusses the research of Josh Tenenberg. (RS)

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Office of Research and the University Graduate School

Volume XVI Number 2 September 1993

Research & Creative Activity

INDIANA UNIVERSITY

ED 361 663

Cognitive Science

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Research, both pure and applied, and creative activities are ongoing and essential aspects of life on the campuses at Indiana University. The quality of instructional education at any institution is tremendously enhanced if based upon and continuously associated with research and creative inquiry. It is significant, therefore, that the emphasis at IU not only is placed upon fundamental and basic research but also is directed toward developmental activities designed to discover those applications of research that characterize the efforts of many of our faculty in the arts and sciences as well as the professional schools.

As an overview of the diverse and interesting programs of research, scholarship, and creative activities conducted at Indiana University, *Research & Creative Activity* offers its readers an opportunity to become familiar with the professional accomplishments of our distinguished faculty. We hope the articles that appear in *Research & Creative Activity* continue to be intellectually stimulating to readers and make them more aware of the great diversity and depth of the research and artistic creativity underway at Indiana University. A full and exciting life is being created here, now and for the future. From our readers we welcome suggestions for topics for future articles in *Research & Creative Activity* that will demonstrate further the scholarly activity at Indiana University.

Research & Creative Activity

INDIANA UNIVERSITY

Volume XVI Number 2
September 1993

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A Cartesian concept of the mind as the inner engine of behavior. Photography illustration by Kent Phillips, © 1993.

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From the Editor

In this first issue of *Research & Creative Activity* for the 1993-94 academic year, you will notice a number of changes as a result of an extensive review of the magazine, as well as changes in the staff over the last six months. Before I welcome the new staff, I would like to formally thank Professor Helen Nader (History) for providing superb editorial leadership for *Research & Creative Activity* from 1988 to 1992. I followed Professor Nader, as the Editor of the magazine in 1992. Michael Shermis joined the staff, as Associate Editor, in February 1993, and has been instrumental in making the magazine available electronically through Indiana University's computing system (at the AIE prompt, type "rca"). By the time this magazine goes to press, Professor Ann Carmichael (History) will join the staff as coeditor. Ann and I will work jointly on some issues in which we have common interests, and separately on some of the more specialized issues. I am delighted, along with the other members of the magazine staff and the Advisory Board to welcome Ann and Michael to our staff.

The overall purpose of the magazine remains the same, as is stated in our mission statement on the inside front cover of the magazine. We have, however, altered the content and the format and would like to point out a few of these changes to our readers. You will probably notice the insert in the middle of the magazine. There are a number of exciting programs and initiatives that influence undergraduate and graduate learning at Indiana University's various campuses, schools, and departments that do not quite fit in the overall goals of *Research & Creative Activity*. In an attempt to provide these programs with a venue, we are expanding the scope of the magazine by highlighting them in inserts when possible. This issue features undergraduate research experiences at Indiana University Purdue University at Indianapolis. As Executive Vice Chancellor and Dean of the Faculties William M. Plater states, ". . . we are 're-engineering' general education with the goal of ensuring that our graduates can succeed in a highly complex, rapidly changing socially, economically, and technologically interdependent global environment."

To gather new ideas and to review the present status of *Research and Creative* Activity, we recently collected information from our readers. Overall, our readers are pleased with the quality of the magazine and would like us to continue with minor changes. Some of the suggestions were to add a section on book notes, to cover more researchers and scholars in an issue, and to investigate a wider variety of topics with greater recognition of interdisciplinary contributions. The request for book notes has been incorporated in this issue with the inclusion of a new column, "From Inquiry to Publication: Books by Indiana University Faculty Members." Our first call to the faculty for recently published books resulted in well over 40 responses. Twenty-seven of these books were selected for this issue. We hope our readers will choose some of the listed books for their own reading or recommend them to others. We also are hoping to include a column in the next issue that will contain abstracts of the latest discoveries by Indiana University researchers.

As we have done in the past, occasionally we will invite an expert in the field to write a guest editorial on the topic to which the issue is dedicated. Thus we will give a person intimately involved with the field an opportunity to discuss the overall view and the interdisciplinary aspects of the topic. In this issue we have invited the Luther Dana Waterman Professor of Psychology and Director of IU's Cognitive Science Program, Richard Shiffrin, to briefly discuss Indiana University's role in a newly developing branch of Cognitive Science, dynamical systems approaches to cognition.

Professor Ann Carmichael and I would like to hear your suggestions and comments about the changes that we are making, topics that we may cover in the future, and improvements for our magazine that properly recognize the scholarly activities of the Indiana University faculty. We may be reached by E-mail (sonip@indiana.edu and carmicha@indiana.edu). Finally, I would like to draw your attention to the response card that has been inserted in this issue and will be repeated in the next two issues. It is important for us to hear from you so that we can update our mailing list and make sure that you keep receiving the magazine.

P. Sarita Soni
Professor of Optometry
Special Assistant for Research
Office of Research and the University Graduate School

Guest Editorial

The following five articles highlight the research of five members of the Indiana University Cognitive Science Program. The research efforts are related by a concern with complex problems in cognition, and attempts to find answers through the use of dynamical systems. Dynamical systems approaches to cognition represent a new and exciting branch of the field. Indiana University is known for having what may be the world's leading research center in this newly developing area.

Although the Indiana University Cognitive Science Program was started in 1989, it has already achieved an international reputation for its innovative and eclectic approaches to cognition, for its academic program, and for the quality of its faculty. In 1992 Indiana hosted the 14th Annual Meetings of the Cognitive Science Society. Cognitive Science deals with all approaches to complex cognition: experimental explorations of what humans do, experimental tests of how we do it, the development of models to explain how our minds work, and the development of computer simulations to demonstrate concretely how the mind might accomplish what it does. The domains of inquiry cover everything humans do, from perception to language, from attention to memory, from learning to teaching, from storage to retrieval, from the development of skill to problem solving, from motor behavior to speech production. Students are allowed to obtain joint Ph.D. degrees in Cognitive Science and a home department. There are already 94 graduate students in the program. There are 47 core faculty, and 50 associate faculty, from 19 departments in seven schools in three campuses at the university.

What are dynamical approaches to cognition? In essence these are models of cognitive processes taking place in time, and evolving over time. Although it could well be argued that all thought has this character, the development of the field until quite recently has treated cognitive processes as a largely static form. The dynamical approach opens up an enormously rich field of investigation, but at the cost of a great increase in complexity. New techniques of great technical difficulty are required such as the analysis of non-linear dynamic systems, the study of chaotic systems, and the analysis of time-dependent changes in neural networks. The applications of this research involve complex and interesting behavior, including the development of walking, the learning of conceptual systems, the perception and retention of faces, the nature of problem solving, and the production of speech.

The concentration of expertise in dynamical systems in Cognitive Science is represented not only by the faculty highlighted in this article, but by the other faculty that meet regularly in the study group Dynamoes, headed by Dr. Geoffrey Bingham in Psychology, and including Drs. Esther Thelen from Psychology, David Jones from Sociology, Beverly Ulrich from Kinesiology, and Richard McFall from Psychology. The Cognitive Science Program has introduced a new course this year, Introduction to Dynamic Systems in Cognitive Science, to be taught by Dr. James Townsend. The faculty in this area hosted, in 1992, the first of a series of international conferences: the First Annual Conference on Dynamic Models in Cognition. Drs. Linda Smith and Esther Thelen have written a book titled *A Dynamical Systems Approach to the Development of Cognition and Action*, and edited a volume titled *A Dynamical Systems Approach to Development: Applications*, both to be published shortly by MIT Press. Drs. Robert Port and Tim Van Gelder have edited a volume titled *Mind As Motion*, also to be published by MIT Press. We believe this activity to be the start of a long-lasting program of research and teaching at Indiana University aimed at dynamical approaches to cognition.

Richard M. Shiffrin
Luther Dana Waterman Professor
Director, Indiana University Cognitive Science Program

Robert F. Port searching for equilibrium with his Slinky

A Matter of Time

Robert F. Port, associate professor of cognitive science, of computer science, and of linguistics, holds a Slinky. Extending his arm at shoulder length, he drops the bottom of the loosely wound spring while holding the top in place. The spring bounces, quickly and distinctly at first, and then it begins to slow until it is nearly at rest. Port says, "It has an equilibrium point. First it will overshoot that point, and then it will oscillate for a while before it settles down and reaches the equilibrium point."

Port could have used a mathematical equation to demonstrate this concept, which he and other researchers in the Cognitive Science Program see as a framework for modeling the way the brain processes most stimuli—including the sounds that occur in our environment. He mentions how revolutionary an idea it is to try to use such "dynamical systems" to model sound perception and language understanding, and he says that in linguistics, the focus is traditionally on the static units of sound production and perception—that is, on units such as words and phonemes. In his enthusiasm, Port jumps from his chair and begins figuring on his office blackboard. He draws a chart that illustrates a case in which an artificial neural network model recognizes two different sequences of sound stimuli, which he symbolizes as *ABC* and *BAC*. (Also called a connectionist model, an artificial neural network is a computer program that has a number of independent units, each of which has some level of activation. Each unit sends signals that excite or inhibit the activation of certain other units, depending on how they are connected to one another and according to fixed rules. Some of the units, or "nodes," get input excitation from the "environment"—thereby modeling sensory neurons. Although these models are greatly simplified, certain similarities exist between the nodes of such a model and the chemically-based firing of neurons in a nervous system.)

Both of the simple sound sequences that Port has drawn end with the "sound" he calls *C*. But what interests him is the space on the chart just before the *C* (the last stimulus in each

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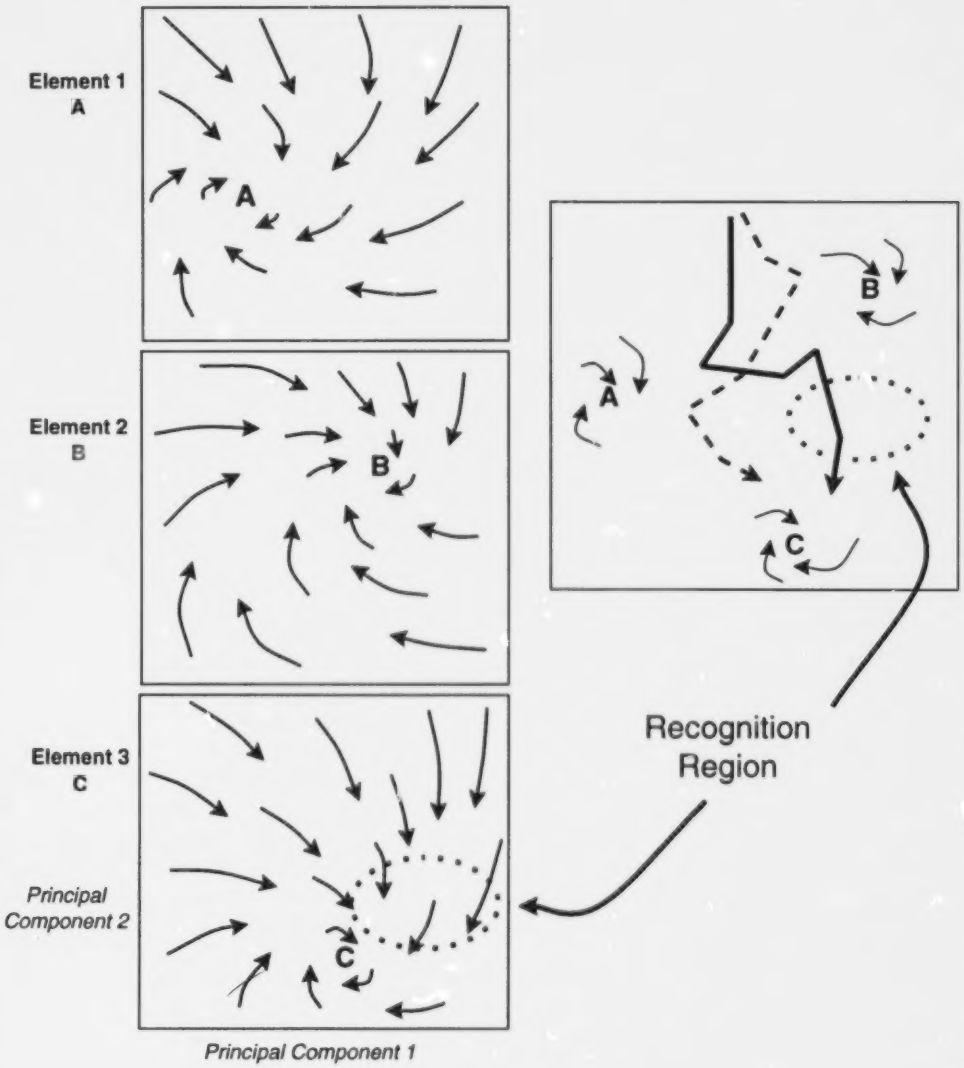


These four panels all represent the same thing, two perpendicular dimensions of the seven-dimensional state space of a network. This model can tell ABC *from* BAC*—and also* AAABBBCCC *from* BBBAAACCC*, etc. When* As *are input, there is an attractor created, as shown in the top left panel, and the state of the system moves toward that attractor in discrete steps, as shown in the panel on the right with a solid line. The arrows in the left-hand panels show there is a vector field that will draw the state of the system toward* A*. The farther from* A*, the more quickly it moves—as suggested by the longer arrows. Then, when* B *appears, a new attractor is created somewhere else (shown in panel B), and the system state begins stepping toward the* B *attractor. The attractor for input of one or more* Cs *finally draws the system state through the recognition region, where it responds as having seen some* As*, then* Bs*, then* Cs*. If the sequence is* BAC*, then the dashed path would be followed, and recognition would not occur.*

sequence). Port points at the paths between the next-to-last and the last stimulus in each sequence, noting how different the trajectories of the two paths are. This scrutiny of what comes between the generally recognized units of sound recognition is driving Port's current research into dynamical systems, an interest he shares with colleagues Tim Van Gelder and Linda Smith. Scrutiny of how a nervous system responds at each instant of time—even while input to the system is itself continuously changing—has become the driving theme of Port's career.

Port's research focus has always been on issues that "fall through the cracks" of traditional linguistic and acoustical theory. Though most linguists concentrate on the symbolic description of language, Port studies temporal—or timing—structures, such as the rhythm and duration of sounds, especially the sounds of speech. Describing his early career, Port says he was "interested in the temporal properties of language, and the way in which relative durations of the parts of the speech signal play a role in distinguishing words, and how listeners could tell one word from another word by details of the timing pattern."

For example, in a series of experiments in the early 1980s, Port examined the result of changing the duration of vowel sounds within actual words. He wanted to see how changes in these durations would affect intelligibility. "If we take a typical pronunciation of the word *rapid* and lengthen the first vowel in small steps, it will eventually sound like the word *rabid*," he reported. This finding challenged the prevailing view that the recognition of a spoken word depends only on the sequence of its component phonemes (the letterlike symbols that are traditionally accepted as representing the smallest units of speech).

Although this cartoon pokes fun at the popularity of electronic drum machines, it also reminds us of how much fun it is for most people to entrain their bodies to periodic patterns—whether singing songs together, doing military drills, or whatever.

In conducting those experiments, Port used synthetic speech to produce the sounds. A sound spectrograph recorded their frequency, duration, and intensity and produced a display on paper of the sounds, which Port measured with a ruler. But he became dissatisfied with these methods. How closely do these operations resemble what happens in a human brain? A spectrograph creates longer pictures of extended sounds and shorter pictures of brief sounds, but Port doubted that the brain produces an analogous display. "There has never been any direct evidence that people have any physical picture for events in time," he says. "How is it, then, that human listeners are able to listen to speech and understand it? How do they remember the beginning of a word when they get to the end? Especially when you consider that speakers can speed up or slow down their pronunciation and warp it in other ways?

"So," says Port, "that concern led to my work on neural or connectionist networks, trying to discover a model for how people could recognize durational patterns and measure time. And to answer the question 'How do we learn complex temporal patterns that have time as a variable parameter?' I'm doing less work on the phonetics of specific languages now and more work on just trying to build an auditory model that could recognize temporal sound patterns of any kind—footsteps, melodies, or whatever—and that I hope will someday recognize *rapid* and *rabid* and tell each from the other in the way that humans do." Under Port's guidance graduate students are working in three IU laboratories: the Artificial Intelligence (AI) Laboratory of the computer science department, the Phonetics Laboratory in the linguistics department, and the Hearing and Communication Laboratory of the Department of Speech and Hearing Sciences. Graduate students working in the AI Lab have written neural network modeling software that they use to recognize temporal patterns.

But the temporal patterns of speech are too complex for the software to recognize now. Port and his graduate students are at an earlier stage—detecting temporal patterns in simple sequences of stimuli, such as a series of tones, or even just a regular series of clicks. "The basic problem of how to recognize *any* temporal pattern is not solved," Port says. "There is no good model for human sound perception. We're not trying to refine a model that exists; there isn't any idea at all, other than what I call the Time Window Model—like a sound spectrogram, and that's not plausible psychologically. With a time window we use a timer to display the signal so that equal distances represent equal time intervals. But we just don't have such a physical representation of time in our heads."

According to one of Port's doctoral students, J. Devin McAuley, even though their neural network models are not yet perceiving speech, they are yielding much interesting information about how organisms self-organize (or adapt) to recognize the important auditory patterns in their environment. In one current experiment, McAuley says, the network "is given a wide variety of sound sequences, then on its own it gradually becomes selective for the sequences that occur most often." Training the computer program to do this duplicates a capability of human and animal brains that is evident in nature, McAuley says. "Humans and cats both spontaneously learn the common sounds in their environment—even if they don't have names for most of them. If you want to make your cat lift its head and look at you, then you can do it by making a novel or unusual sound."

The research that Port, McAuley, and other graduate students, Sven Anderson and Fred Cummins, are conducting is funded by grants from the U.S. Office of Naval Research. The Navy, with its need for accurate sonar equipment, is interested in any information Port and his students can provide about how humans process complex sound patterns. Their data come both from their experiments with computers and from experiments with human subjects. "There are two parts of this project now," Port says. "One part is designing these networks that can recognize temporal patterns or produce them. The other part focuses on human listeners." In the second kind of experiment, using the methods of his colleague Professor Charles Watson of IU's Department of Speech and Hearing Sciences, Port says, "we make up a complex pattern that listeners have never heard before, so we can see what factors make them do better or worse at processing the pattern. The patterns sound a lot like an automatically redialed Touch-Tone phone number. So in each trial the subjects hear, we might play a random 'phone

number' and then the same 'number' again with maybe one digit changed. (We aren't really using telephone sounds, but that example gives you some idea of the patterns.) The first thing to note is that telling the beeps of 333-7854 from those of 333-6854 is very tough when the patterns are presented at such a rate. Telling the 6 from the 7 is not hard if you just hold down each button for as long as you want. So why is it so much harder to tell 6 from 7 when they are embedded within the other numbers? The important result that Watson established is that if you have enough practice, you can learn any *particular* phone number when presented this way. It might take 50 hours of practice on *each* phone number to learn it, but you can learn to recognize particular complex patterns extremely well."

Port and Richard Shiffrin designed this logo for IU's Cognitive Science Program.

Why is it so much harder to hear the altered tone when it is embedded in a sequence? "It appears that the complicated patterns have so much information in them, listeners can't locate the portion of the patterns that contains the change," Port says. "Notice how different this is from English speech. If I say 'Bill just said *bit* to his friend' and then I say 'Bill just said *bet* to his friend,' you have no difficulty at all telling which was which. So it appears that it is our extensive experience with the sound patterns of English that is critical to our ability to recognize speech." What would be required for a listener to tell two tone sequences apart? How many trials are necessary to reach optimum performance on this task? Catherine Rogers, another of Port's linguistics graduate students, has been conducting experiments to answer this question. It turns out that subjects need thousands of trials before they can detect the frequency change in these complicated tone patterns as successfully as they can when they are "unmasked." Port and his students are applying this information about the role of extensive practice on specific sound patterns to the design of their neural network models, with the aim of eventually creating a computer system that recognizes speech, something McAuley says computers still do not do well.

"There are systems that are said to recognize speech," McAuley says. "But they still make lots of mistakes. They also have a limited vocabulary—you can't say just anything, but only a certain set of words, without much noise in the background, and you can't vary your rate of speech very much." Again, it appears that understanding temporal issues is a key to advancing the technology of speech and hearing. McAuley considers his research experience with Port in the IU Phonetics Laboratory highly rewarding. He says that Port has provided him with an opportunity to develop a "pure fascination for how the brain works at an abstract level." McAuley foresees many practical applications of the knowledge gained from the neural network model research. He says, "If we develop a system that can translate sound into visual information (such as a stylized speaking face), that technology would be useful in a telephone for deaf people who can lip-read." McAuley adds that he thinks the research on temporal patterns may also help people who have speech disorders. "It may turn out, for example, that there is a biological basis for stuttering that has to do with arrhythmia," he says.

Not all of Port's current research is focused on neural network models. He also hopes to apply his theories about temporal and rhythmic properties of language to the development of a device that will help speakers of foreign languages improve their English pronunciation. Port has noticed that speakers of certain languages, especially Asian languages, have great difficulty being understood when they speak English. As in his earlier phonetic experiments, Port suspects that differences in phonemes are not the main problem. "My hunch is that Japanese speakers, for example, are using a Japanese-style speech rhythm instead of an English-style speech rhythm, and this throws us off," he says. "We can't tell the long vowels from the shorter vowels or the stressed syllables from the unstressed ones. I think that's the biggest contributor to unintelligibility of many kinds of foreign accents—not confusing the phoneme *r* with *l*, or specific things like that."

Port plans to conduct listening experiments to determine the aspects of foreign-accented speech that make it hard to understand. Then he will use the data he has gathered in the development of a teaching method that would use speech recognition technology to supervise pronunciation drills for nonnative English speakers. These drills would employ a device designed by his wife, Diane Kewley-Port, who is a professor of speech and hearing sciences at IU. She, Charles Watson, and IU professor of mathematics Daniel Maki received a National Science Foundation grant (through their company, Communication Disorders Technology), to develop and market this computer-based device for training children to overcome articulation disorders. They and their chief engineer, Jonathan Dalby, one of Port's former Ph.D students, now plan, based on Port's research, to redesign their device for foreign accent training. After extensive testing, they hope to market the device. "For me, it is surprising to discover the possibility of technology transfer from my academic work into a business," Port says.

Foreign language acquisition has intrigued Port since his undergraduate days in the late 1960s, when as a Peace Corps volunteer in Kenya, he learned Swahili. "I was very much aware that in learning to speak this language as Africans do, I was reconstructing the way I use my vocal tract," he says. "It was as if my whole mouth became something new; when I spoke Swahili I felt as if I was creating a new instrument there that I didn't have before." Though at the time he was a sociology major not yet trained in linguistics, Port knew that an explanation of this sensation that relied just on a string of letterlike sound units would not suffice. "The letters that you use to spell a language are just the beginning," he says. "Just the crudest description. I was not learning to make new letterlike sounds. . . . I was learning a new speech rhythm. I was creating a new dynamical model with my tongue and lips. It's the same as when you learn to dance. You learn how

to make your whole body into a kind of 'cha-cha machine.' It's not just a matter of doing Step A followed by Step B. To do it well, you must remake your entire body into an entirely new dynamical system—into a kind of specialized Slinky—a Slinky that cha-chas. So just as a Slinky 'wants' to oscillate—and it doesn't matter how you poke it, it oscillates more or less the same way—similarly when you have learned to cha-cha or learned to speak French really well, your body wants to just keep on doing that, and impossible cha-cha steps and impossible sounds for French hardly ever happen."

"There are things that you think you know, but when you look a little closer, you find that they dissolve. The things you were sure you could hold onto will slip through your fingers like sand."

When Port returned to the United States, he completed his undergraduate degree at Johns Hopkins University and then weighed his options. An amateur musician, he considered studying ethnomusicology, but he discovered that scholarship in the field was grounded more in the humanities than in the sciences. "Linguistics seemed to be a more basic science," he says. Port earned an M.A. in linguistics at Columbia University in 1972 and a Ph.D. in linguistics at the University of Connecticut in 1976. His dissertation investigated temporal patterns in the pronunciation of English words such as *rabid/rapid* and *fuzzy/fussy*.

During his training Port was inspired by the work of cognitive scientists Karl Lashley and J. J. Gibson. Port says, "Lashley was one of the first people who focused attention on the problem of temporal patterns." Gibson, who conducted studies at Cornell University on vision, "was interested in the richness of stimulus information," Port says. "Just as there is a tendency in phonetics to think that what people are listening to when they listen to speech is just the phonemes, there has been a tendency in studies of vision to think that what we perceive is constructed from little objects that we assemble mentally. But Gibson emphasized looking at the holistic information in the stimulus. My study of rhythm and temporal patterns of speech is another way of doing what Gibson was encouraging researchers to do."

The mind's ability to recognize "holistic" patterns can be witnessed whenever the human auditory system must distinguish among competing stimuli to track a desired signal. For example, Port says, "we're incredibly good at talking to people amid the chatter at cocktail parties." A demonstration of this concept that Port uses in his introductory cognitive science class is a recording of the spoken phrase *comparable combos of features*. The voice is heavily overlaid by rattling noisemakers, a competing voice, and tapping pencils, but it is still easily intelligible. Examining a spectrogram of the recording, Port says, "Visually it's hard to find the target phrase on this picture. But humans can track that voice by means of short-term prediction. Humans have the ability to do that, and the models we are developing in the lab are designed to do that, too—at least if all goes well."

Besides teaching basic phonetics courses, Port teaches surveys of linguistics, acoustics courses, experimental phonetics courses, and a graduate survey of cognitive science. He says, "The graduate survey is a daunting course to teach because the students come from many departments—psychology, computer science, philosophy, linguistics. And I have to teach basics in all of these disciplines—even though some students in the class are likely to know much more about a given topic than I do." He also visits undergraduate Swahili courses every semester to speak in that language to the students. "It helps me keep my Swahili going," he says, noting that it has been 25 years since he has visited East Africa. This fall Port is teaching a graduate seminar on the structure of speech sound. The course, he says, is "based on a novel theory about how sound structure works in various languages. The theory is built on a dynamical model of motor control, modified to account for speech production. The theory has a lot of mathematical material on dynamics that linguists don't yet know much about, so in this course we will review the theory and evaluate how good a model this would be for production of speech."

Port enjoys teaching precisely because he can involve his students in research. He says, "The pieces from which languages are built are hoped to be very simple—letterlike, symbollike, wordlike. But I think they're not so simple, not as discrete as you'd hope. So I'm always trying to show students how hard it is, that we can't just make simple assumptions and expect to make sense of things.

"What I've learned is that the things we think we know, we usually don't know. Take even the simplest questions, such as 'What are the pieces that an English sentence is made of?' The words of a sentence all seem nice and separate, and you can look up each word in the dictionary, and everyone knows what those words are. But when you look more closely, it's not so clear whether the words are the right pieces after all. "If I say 'I found it,' is the word *found* one meaningful piece or two? That is, is it *find* plus Past Tense? Or if you just ask about the sounds, is the vowel one vowel or two? What about the fact that the *n* in *found* overlaps with the vowel and is sometimes missing altogether as a distinct segment?" Port points to his wall, where he has attached a bumper sticker that reads, "Question Reality." He says, "There are things that you think you know, but when you look a little closer, you find that they dissolve. The things you were sure you could hold onto will slip through your fingers like sand. I think that makes life interesting. It makes teaching fun."

—*Karen Grooms*

Perceiving As a Complex System

Linda Smith, Professor of Psychology, Indiana University Bloomington

Imagine a horse moving across an open field. From a walk it changes to a trot, from a trot to a canter, and from a canter to a gallop. The increase in speed at the moment of each change is slight, but the four gaits are qualitatively different. The whole biomechanical system of the horse reorganizes itself to make the changes and it presents to our view radical variations of motion. We could almost be watching four different animals.

But of course we are not. There is only one system operating here, which is why IU Professor of Psychology Linda Smith uses the changing gaits of the horse as an analogy for the way perception changes in human beings as they develop from child to adult. "What I really want to understand is what the structure of conscious experience is," says Smith. "Why do I *see* you the way I do? Why is the immediate experience the way it is?" Those questions give rise to problems in perception, as well as to problems of attention. And the fact is, says Smith, that children and adults perceive and attend differently.

For a long time, says Smith, researchers in the psychology of human development have observed that perception, or the structure of immediate experience, changes from being holistic, when we are very young children, to being analytic and differentiated as we grow older. As a description of the data, this principle is accurate, says Smith, but we have to ask ourselves: What makes it that way? What causes the change?

Most of the psychologists of the late nineteenth and early twentieth centuries talked about children as if they were a totally different species, says Smith, with their own holistic perceptual system. Then development happened, some "magic," and the child began to use a different kind of system. It was as if the child and the adult had two different ways of perceiving.

The difference between a holistic and an analytic way of perceiving is easily illustrated, says Smith. Let us say that your goal is to compare two cups. To do this your perceptual system has to accomplish a myriad number of tasks simultaneously. It has to determine the cups' features, dimensions, colors, shapes, locations, shadings, and so on. If you are a child, you compare one whole cup to the other whole cup, all at once, and make decisions globally. You can make judgments like "same" or "different," says Smith, but it is very difficult for you to make judgments about specific features of the cups, like color, for instance. Your decisions are which cup to reach for, or which to call a cup, or which to drink from.

What you can say about the two cups if you are an adult is that they are roughly the same shape at the top, they are different colors, they are in the same location, or they have different textures. As an adult, you can make judgments one at a time in very articulate, analytic ways. And, if it matters for some purpose, you can increase the weight of some features, so that you might emphasize hardness or color over size or shape. You are not holistic. Your perceptions are more differentiated and analytic.

But these observable variations in perception do not signify that children and adults are different in kind, says Smith. "What I showed in my early work was that there was one perceptual system that was very much the same for very young children and adults and that it was a nonlinear system: its parameters have to change only slightly to produce what looks on the surface like qualitatively different ways of perceiving." What Smith developed was a mathematical description of how the mind—as one system— perceives holistically or analytically, how qualitatively different outcomes, qualitatively different stable states, can arise simply by changing the values of the mathematical control parameters.

"I'm positing two control parameters," says Smith. "I can explain the data with two." One is the degree to which the

Which features you attend to the most on these animals will determine which of the animals are most similar.

system can inhibit, or temporarily ignore, some aspects of experience. This parameter is called "weighting," and it allows the system to selectively attend to one dimension and to discount others. For example, suppose you are presented with three pictures, a bat and a crow, both flying and both dark colored, and a pink, standing flamingo. You are asked which two are similar. If you weight overall shape and color more heavily, says Smith, you will perceive the crow and the bat to be most similar. If you weight features like beaks and feet heavily, the crow and flamingo will be the perceptually more similar pair. Which two objects in the group are the most similar depends on which features you attend to the most. In mathematical terms, weighting can range from zero (no attention) to one (complete attention). For very young children, says Smith, all dimensions are weighted equally, so if there were just two dimensions, the weighting for each would be .5, which explains why they do not selectively attend to individual features. In adults, weighting is constantly changing, as they attend to this, that, and the other dimensions, at will.

Smith calls the second control parameter "distance," and defines it as a measure of how discriminating we are in our perceptions. If you are asked whether an object is red, for example, would orange be close enough? Would you reject fuchsia as being "not red?" Smith says that children will identify a relatively wide range of colors as "red." They generalize broadly about what is close to the target value and can be called undiscriminating. Adults are much more particular in their discriminations and will accept a relatively narrow range of values for the target value. Discrimination increases steadily with development, says Smith.

For her work in explaining how a single perceptual system can produce both holistic and analytic perceptions, Smith received the Award for Early Career Contribution in 1985 from the American Psychological Association. In that same year she was appointed a full professor at IU, only eight years after starting her teaching career here.

Smith's interest in psychology and in the structure of conscious experience dates from midway through her undergraduate years. She considered entering college in

mathematics or English, but she won a national woman's engineering scholarship and chose to enter that field at Northeastern University in Boston. And at the end of her sophomore year she transferred to the University of Wisconsin at Madison—looking for a major other than engineering. The problem with engineering, says Smith, is that there is little allowance for general electives. "This was the middle of the Vietnam war and [a steady diet of engineering] was not relevant. I wanted to take something like The Sociology of Poverty. I wanted some relevance." So she became a mathematics major to get more electives; one of those electives was psychology. "Prior to that course I did not have a good opinion of psychology. But I was pleased to see what it did and I liked it."

Smith's future work was anticipated and, in fact, defined by a part-time job as an undergraduate, testing severely retarded children for a developmental psychologist at the university. In a typical experiment the children were asked to find a piece of candy placed under either a square or a triangle. They could do this, says Smith. They could learn that the square gets them the candy. When the test became multidimensional, however, when they were faced with the same two shapes but now in two colors (with the squares still hiding the candy), the children were lost. They could not learn that the choice of the square would always "win," and color does not matter, even after thousands of trials.

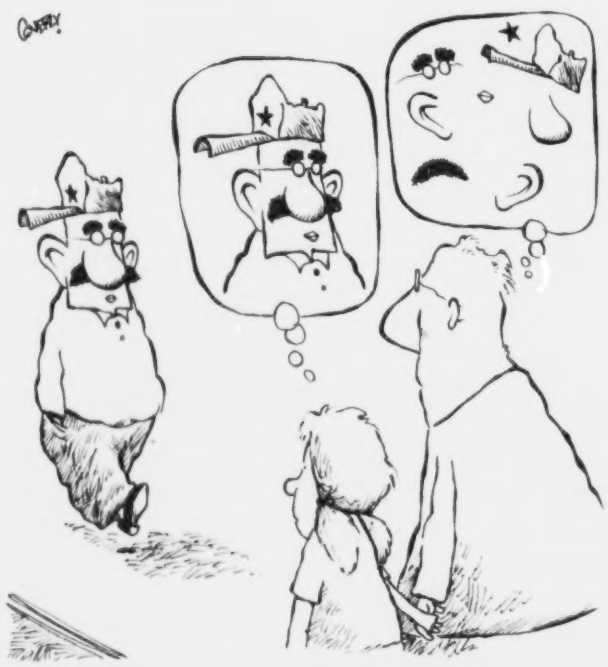
"It really bothered me. For an adult, the answer is obvious: it is either shape, color, or position that determines the reward." But the children never made that deduction, and Smith thought the reason for their failure was that they were retarded. "Lo and behold, I found out it's not just retarded kids who can't learn this. A three-year-old destined to be a rocket scientist can't learn this. It's everybody. I kept thinking, now why on earth should this be? What are they seeing? How are they representing this problem? How can they miss it?"

They miss it, says Smith, because they do not selectively attend. They are holistic perceivers and they cannot discount some features, such as color, and pay attention only to others, such as shape. "This was the defining problem I started with in graduate school: what is it that makes young children unable to selectively attend. I've actually been working on the problem ever since."

Smith says the logical conclusion of her early work on the human perceptual system is that perception is not static. "People have said for a long time that perception is very much like taking a picture and that you're stuck with that picture. But, in fact, perception and our immediate experience of the world is not static. It moves. So that when I look at you right now, I may emphasize some things more than I did five minutes ago. I may see you differently."

The dynamic, changing nature of perception is easy enough to demonstrate, says Smith. You are reading this article in English, but what if it was suddenly transformed into a language you do not know, for instance, Arabic. The characters that make up the words would be meaningless to you: your perception of them would not be the same as that of an Arabic speaker or as your own if you were to learn that language.

Or consider, says Smith, the words "CAT" and "THE." These words can be written so that the A and H are formed identically, the sides of the letter angled inward at the top but not touching. Without hesitation, your perceptual system reorganizes itself, says Smith. You see the letter that is neither A nor H as the letter appropriate to its context—you literally see it differently in each word. What you know and what surrounds your perception changes that perception.



Children view reality wholistically, that is they use all the information and cannnot emphasize some parts over others. Adults view reality analytically, that is they use information in pieces and can emphasize some pieces more than others.

Given, then, that the human perceptual system is singular and dynamic, Smith came to the conclusion "that the system is a whole lot smarter than people were giving it credit for. What I've been arguing recently is that this kind of system can be very smart. Once you let it move its weights around and shift what it attends to and be context specific, although it's really just about perceiving, it can get you very intelligent behavior."

There are, however, two views about what counts as intelligence, according to Smith and her collaborator Susan Jones, IU assistant professor of psychology. Their recent article, "Cognition without Concepts," in the journal *Cognitive Development*, speaks to this issue. The traditional, or structuralist, view identifies intelligence—what is smart about human cognition—as represented knowledge. In this view, say Smith and Jones, an abstract equation (2 + 2 = 4) is the highest form of intelligence. This kind of knowledge is thought to be useful because it is constant and applies across contexts, across individual acts of cognition and individual categories.

The other view of intelligence challenges these traditional beliefs. It states, according to Smith and Jones, that "what is

smart about all of human cognition is its continuous exquisite adaptiveness to the particulars of real external (and also internal) events. Perception—contact with here-and-now reality—matters . . . in individual acts of believing, intending, feeling, and realizing." In this view, says Smith, knowledge is not constant across all contexts, "but adjusts to fit the real world's nitty gritty, messy demands. [This knowledge] says, well, you know, when I'm dealing with my Uncle Sam, two plus two sometimes equals three and a half."

"So, what makes a child go from sitting up, to walking, to talking, to dating, to graduating from high school is not one thing marching along, but several complex things, all of which interact with each other."

Because perception moves, says Smith, and because it moves intelligently, it can do much of the work that people have been attributing to higher level conceptual operations. Smith is attempting to prove that assertion in her recent collaboration with Michael Gasser, assistant professor of computer science and linguistics at IU. Gasser writes computer programs modeling the weighting and distance changes that occur when human beings perceive. "He starts the computer off like a little brain," says Smith. "The program simulates a mass of individual units that act like neurons, either firing or not firing. He builds a network of connections, between layers and layers of these units. The network is not smart at first. But it learns to perceive and compare objects and in learning it follows the same developmental trend that people do—from holistic to analytic perception."

This form of computer simulation is known as connectionist modeling. It is patterned on the operation of the human brain, says Smith, which is more interactive, more redundant, more chaotic, than any typical computer. The computer does not learn the equations and then act, just as human beings do not have equations in their heads to guide their judgments and decisions. After all, says Smith, equations are just descriptions; they do not make anything happen. But the computer acts, she says. It learns to selectively attend.

Experiments in artificial intelligence performed recently by Gasser and Smith illustrate the point. It is well established, says Smith, that children learn to label objects with nouns, such as "block" and "dog," earlier than they learn to label objects with dimensional adjectives, such as "big" and "red." Smith theorizes that because noun meanings usually involve many dimensions (for example, color, texture, and size), they are in some sense more limited and, therefore, easier to learn. Adjective meanings, on the other hand, involve only one dimension (such as color), are less limited, and as a result involves more uncertainty about what defines their category.

Gasser's computer program was written to support this theory. The goal was to get the computer to learn to say, for example, "green" when shown a green circle and asked "What color is it?" to learn to say "round" when shown the same figure and asked "What shape is it?" and to say "pea" when show the same figure and asked "What is it?" The experiments clearly demonstrate that learning in a connectionist model follows the same pattern as learning in the human brain: nouns come faster than adjectives. What the results suggest, say Smith and Gasser, is that nouns and adjectives do not differ in kind, as has been believed, but rather by degree, supporting Smith's belief that human beings are best understood as a single but complex nonlinear system. The results also suggest that connectionist modeling can be a powerful tool for investigating a whole range of properties of human cognition.

The marrying of developmental psychology and artificial intelligence places the work of Smith and Gasser in the new discipline known as cognitive science. For researchers in this field, says Smith, which also includes neuroscience, the questions are: What is intelligence? What makes intelligence? What causes it to change? "People like me, psychologists, know a lot about how people perceive, how they compare, how they learn language, and so on." Similarly, says Smith, people who work in neuroscience and in cognitive neuroscience and people who work with artificial intelligence have made enormous progress in their fields.

It is appropriate, says Smith, for all three fields to come together when investigating theories of intelligence. "It's my stated theory that children and adults perceive in the very same way, and that the outward differences are caused by the shifting of a few components in the perceptual system. If I'm right, I ought to be able to build a computer that can simulate it. And— since I'm not a dualist, since I don't believe that you can separate mind from brain—if my account is correct, it also has to fit with what we know about the brain. I can't go positing stories about perceptual development that fly in the face of what we know about neural development." When a theory is correct, says Smith, scientists in all three fields ought to reach similar conclusions.

Work in one field of the new science, which is only two decades old, can further the work in another. For example, the research into perception that Smith and other developmental psychologists have done has already led to significant advances in the field of artificial intelligence, and it promises to lead to more. Because the most intelligent device on earth is the human being, says Smith, as we discover how humans perceive, we become capable of making computers that perceive. When we learned how humans perceive the letters of the alphabet, we successfully designed machines that can read handwritten zip codes: the post office has them in use right now. When we learn how humans correct mistakes in their perception, we will know how to design a robot rover for the planned Martian space mission, a machine that can perceive an alien landscape and move through it, gaining from its mistakes and solving problems not yet imagined.

One benefit of seeing her work on perception expand into the bigger field of cognitive science, says Smith, is that it becomes increasingly obvious that development, like the brain, is more complex and context dependent than people have believed. The problems of language-disordered

Undergraduate research assistants Dewey Mo..in and Laura Namy work with Nick Wozniak on selective attention. They are asking Nick whether he could "zero in" on the specific properties relevant to naming objects (principally shape) versus those relevant to hanging clothes.

children, for example, may start with a physical difficulty in articulation, or even with chronic ear infections. Those conditions, however, have a cascading effect throughout a child's early life that only later produces what we identify as a developmental disability.

Studies in cognitive science support the view, says Smith, that we need to understand developmental systems as a whole and how one part can affect all the others. "So, what makes a child go from sitting up, to walking, to talking, to dating, to graduating from high school is not one thing marching along, but several complex things, all of which interact with each other."

The mind of the developing human is also not the separate, transcendental entity it was thought to be, says Smith. "We consider the operations of the mind as those of a dynamic system," say Smith and Esther Thelen, IU professor of psychology, in their forthcoming book *A Dynamical Systems Approach to the Development of Cognition and Action* (MIT Press). What else could it be, they say, given that the task it faces is to make sense of the world around it through the operations of a fluid, interacting assembly of neurons. "Minds do not just represent the world," say Thelen and Smith, they are in continual contact with it. "Minds live in and are part of physical reality."

"I think that we, in cognitive science, are part of a paradigm shift," says Smith. As what researchers in psychology, artificial intelligence, and neuroscience have discovered begins to merge, "the whole way of thinking is changing. We are approaching the questions and the phenomena differently."

The value of a paradigm shift in theory is how much new knowledge we gain from the approach, says Smith. The old way of thinking seems to have gone to the well as often as it can and provides no new insights into the data. The new way of thinking says that mind is embodied—it is implemented in the brain—and that perception, which always matters, is intelligently and creatively adaptive. This view is leading us into new frontiers, says Smith, "frontiers that we did not even think about thinking about, that we did not even know we could know."

—Tom Tierney

The Mind/Body Problem Revisited

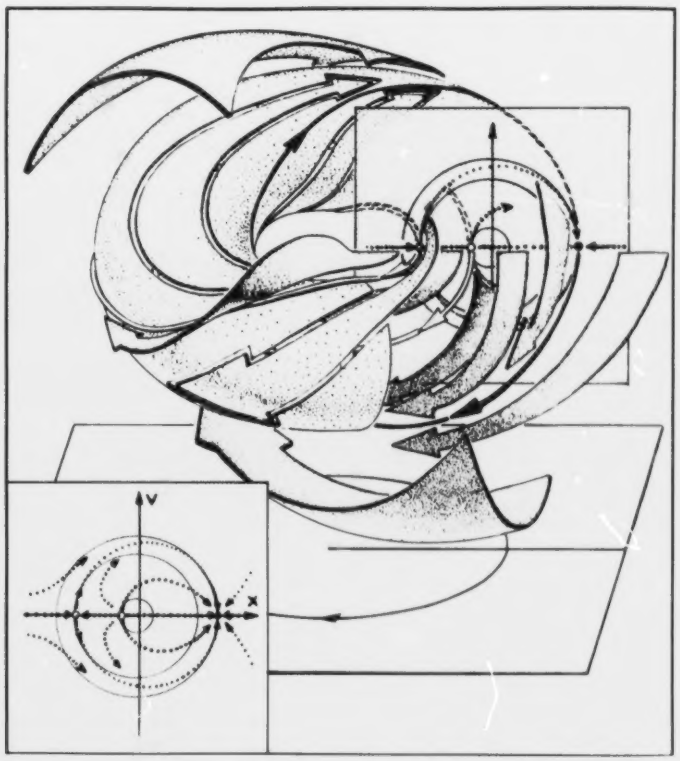
Timothy van Gelder, Professor of Philosophy, Indiana University Bloomington

The first time you meet Timothy van Gelder, do not expect to see a stereotypical philosophy professor. Instead of a tweed jacket, he wears a T-shirt and jeans. His blond hair is cut short, and there is no hint that a greying beard will ever grow from his clean-shaven chin. His office smells of freshly mown grass, not pipe tobacco, and the window opens onto Indiana University's Bloomington campus. The office walls are lined with books about mathematical analysis, neuroscience, psychology, and physiology—not your normal philosophical fare.

But van Gelder has been a member of the IU Philosophy Department since 1989. He is also a cognitive scientist. His work in these areas has won him the Queen Elizabeth II Research Fellowship. This prestigious award by the Australian Research Council, which provides salary and research expenses for five years, is intended to "encourage research in Australia by young postdoctoral graduates of exceptional promise and proven capacity for original work." He will be taking leave from IU and be based at the Australian National University in Canberra for the next five years, but will be back for research visits for one semester each year.

As both a cognitive scientist and a philosopher, van Gelder spends his time asking questions about the way mind and body relate. He says, "I'm interested in mind itself and what mind is, and how it fits with the body." His questions do not stop with the mind, but extend to the nature of the body and the brain. "These are not separate issues," he explains. "The nature of the body is just as much up for grabs as the nature of mind." He is the first to admit that, as far as philosophy goes, his particular field of interest within cognitive science "is highly nonstandard." "As far as I know, there's no other philosopher who's ever thought about these issues from the new dynamical systems perspective that is emerging at Indiana University," he says.

The mind-body problem is not a new question, and researchers in cognitive science approach it in two ways—scientific and philosophical. Those who use scientific methods typically focus on the body in their efforts to figure out how the mind/body system works. "The idea is that once we figure out everything about how the brain controls movement,



A phase portrait of a dynamical system. Pictures like this one are one way to understand the very complex behaviors of nonlinear systems. Cognitive scientists at Indiana University and elsewhere are increasingly using such pictures in attempts to understand human behavior and cognition.

speech, and other functions, then there won't be a mind/body problem after all," says van Gelder. Therefore, once the way the body functions is completely understood, the mind/body problem will cease to exist.

Philosophers, on the other hand, usually approach the mind/body problem from the opposite direction. They focus on the nature of the mind and accept the body as a relatively unproblematic machine. Yet this stance, says van Gelder, makes the mind seem much more confusing and mysterious than the body.

Van Gelder believes that neither of these approaches is satisfactory on its own. "If you're a pure philosopher, you'll have trouble developing a theory that properly integrates what we know about the nature of the human body and the brain," he says. But the traditional scientific perspective does not provide a solution on its own, either. "If you focus only on the mechanics, just on the nature of body, you won't be able to see all kinds of interesting phenomena," he explains. "And you'll never know that you're not explaining these phenomena because you won't see them."

For van Gelder, the solution is to be neither scientist nor philosopher, but a mixture of both. "You have to be both, or at least you have to be aware of and sensitive to both areas at once," he says. So although he uses philosophical methods in his research, he brings a dual awareness to his work. "I'm very glad that there are people out there running experiments and doing studies and growing cultures and studying neurons," he says. "But I'm sure glad I don't have to do that. I like the purely philosophical issues. The deep conceptual issues are the ones that interest me."

And that is philosophy, in van Gelder's terms. He cites philosopher Wilfrid Sellars' definition of the discipline: "Sellars once said that the aim of philosophy is to understand how things in the broadest possible sense of the term hang together in the broadest possible sense of the term." So as a philosopher in cognitive science, van Gelder is trying to do precisely that: stand back and take a look at the big picture. "I try to get at the ideas that people are coming up with," he explains. "Some person might spend years taking detailed measurements of neurons in the brain. And then they come up with the idea that, in order to understand the patterns of firing, you have to use a fundamentally different mathematical framework. And that to me is fascinating—that you need this kind of framework rather than that kind of framework. The actual data is not fascinating in itself. What's fascinating are the deeper implications of it."

"That's one difference between philosophy and the various other branches of cognitive science—the philosopher tends to focus on the bigger questions. Somebody's got to try to see how the field is structured, and how ideas fit together. And that's one thing philosophers are trained to do." But van Gelder has no qualms about using hard scientific data in his research. He takes results provided by people in fields like neuroscience, linguistics, and computer science, and tries to locate those results in the larger scheme of things. "The big pictures are only possible because the details are there," he explains.

Van Gelder's interest in the mind/body problem stems, at least partly, from his experience with the Anglican Church. A believer during his childhood and early adolescence, van Gelder experienced a turnaround in his late teens. "By the end of high school, I realized that none of this is true," he recalls. "God doesn't exist and it's all a great big myth. It's just sociological; it's just ritual." The youthful van Gelder turned to philosophy, where he found the tools that allowed him to demonstrate to his own satisfaction that God does not exist.

"I suspect that my initial interest in the mind/body problem came out of that," he says. "If God doesn't exist, maybe the soul doesn't really exist either. If there's no God, maybe this whole idea that there's something mysteriously different about the mind is wrong. Maybe we're just machines, getting about the world."

René Descartes, the seventeenth century philosopher. Descartes formulated a way of understanding the mind that dominates cognitive science today.

By the time van Gelder completed his undergraduate studies at the University of Melbourne, Australia, he had become an ardent devotee of crude materialism. "I wanted to prove that the idea that there was some separate mind thing was false—just as false as the existence of God," he remembers. And to prove that, he turned toward artificial intelligence systems. "Artificial intelligence seemed to be a way to explain how thinking could go on in a machine—of explaining how mind could be fundamentally just part of the rest of the material universe," he says. He started a master's thesis, intending to prove that the problem of free will could be solved by examining high-level artificial intelligence systems.

But van Gelder's ideas were to be reshaped once again while he pursued graduate studies at the University of Pittsburgh. In Pittsburgh, he found strong programs in philosophy of mind and cognitive science. Pittsburgh was one of the centers of connectionism, the theory that cognition is best understood in terms of networks of neurons, as found in the brain. Connectionism was the most prominent new movement in cognitive science during the 1980s. "I happened to land in a place where I was exposed to a lot of very exciting stuff," recalls van Gelder.

Some of that exciting stuff led him to rethink many of the ideas he had held as an undergraduate. "After a few years in Pittsburgh I realized that artificial intelligence was pretty much dead in the water, as an approach to the study of mind" he says. "We weren't computers after all."

It was with this perspective on the relationship between the mind and the body that van Gelder arrived at Indiana University in 1989. He credits circumstances for the further development of his interest in the mind/body problem. "By pure coincidence, I happened to be at the right time and the right place to have been influenced in a whole new direction," van Gelder says.

It was the right time and the right place for anyone interested in cognitive science. Over the past few years, Indiana University has become the center of a new movement in cognitive science. At Indiana University, people from a wide range of fields, including linguistics, motor control, developmental psychology, and cognitive psychology, are working together to challenge accepted ideas about how the mind and body work together.

For the past thirty years or so, the dominant perspective in the philosophy of mind has been one that derives from the seventeenth-century philosopher René Descartes. In Descartes' view, there were two fundamentally different things in the universe: the mind and the body. The body was a very efficient machine, but there were certain things that it could not do alone. The mind, which could think, enabled the body to function intelligently. Descartes had an elaborate theory about how these two parts interacted to produce one person.

Today, most researchers interested in the mind/body problem work from a perspective that comes directly out of this Cartesian picture. According to this new version of the theory, the substance inside the skull makes it possible for physical actions to take place. Although today's theorists do not believe that this internal machinery is a distinctly different substance, that is the only crucial difference between the modern and the old versions of the Cartesian picture. Mind is still conceived of as an inner engine which is causally responsible for our actions.

Within this general philosophical framework there has emerged, in cognitive science, a dominant theory about how internal processing causes cognition—our perceptions, thoughts, and actions. Most researchers base their understanding of cognition on the model of the digital computer. In this view, cognition is basically computation. "These researchers take the digital computer, which was invented in the 1940s, and use it as the model for understanding how cognitive processes work," van Gelder says.

The computational model suggests that cognition happens through data structures and symbolic representations. The brain uses algorithms to process and manipulate the representations. Perception happens when the physical world impinges on the sense organs and produces these representations. The brain's manipulating these representations *is* thinking; actions happen when a representation of a goal is translated into movement. "The only really good conceptual framework that people have had for the last few decades has come from computer science, in particular the model of the digital computer," he says. "And

The University and Undergraduate Research

Our obligation as an institution of higher education is to ensure that students have the opportunity to develop intellectually as fully and completely as possible. For most students, their undergraduate experience may be the last formal and structured phase of their education, and it establishes lifelong habits of thinking, interpreting, and evaluating. This educational process should not be limited to an examination of existing knowledge, but it should encourage and nurture independent and creative thinking. One effective way to accomplish this is for students to collaborate with faculty in research. IUPUI strongly supports undergraduate involvement with research and offers students educational opportunities beyond the traditional lecture hall setting.

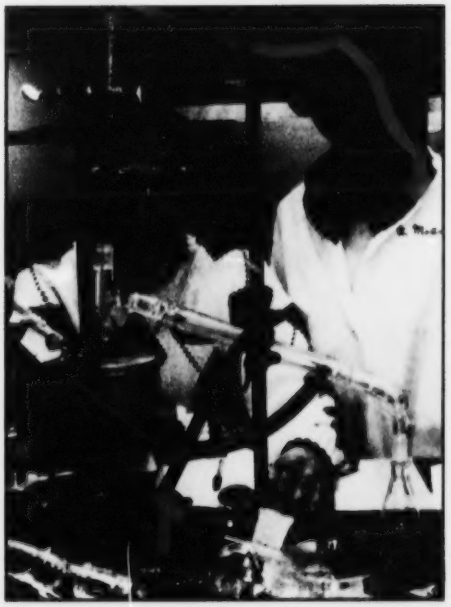
Research: Learning through Experience

The University can provide undergraduates with hands-on, participatory experiences through research. Benefits include:

- the development of skills and intellectual tools necessary to sustain creativity and inquiry;
- the application of effective oral and written communication;
- the opportunity to use modern technology as a tool for discovery and learning;
- the study of books and literature that link new knowledge with the past and reveal the application of methods of inquiry to problems;
- the careful, critical, and accurate analysis of observations, ideas, and aesthetic expressions;
- the means for acquiring data from people and things around us; and
- the self-discipline necessary to carry a project to completion.

Student Diversity at IUPUI

Demographics at IUPUI are not the same as traditional residential campuses. Our new majority student population has become a valuable asset to research programs. These students, usually more mature, have a life experience that can provide an additional dimension to their research involvement. These assets often manifest themselves in a more effective common sense, a practiced critical eye, and a more pragmatic perspective. In recent years, students entering IUPUI directly from high school have shown an increasingly greater responsibility for their own education and have become more involved with the research experience. New high school graduates expect more than just good lecturing from the institution. They want to be involved.



"Knowledge is constructed and verified through collaboration. Collaborative learning gives students a voice in creating knowledge." —*from* Principles of General Education *authored by IUPUI faculty*

Among both new majority and traditional student populations there is a growing number of undergraduates who are best challenged and stimulated by engaging them in meaningful work that permits them to grow intellectually. These students often excel most in non-traditional situations and activities. They are at their best, not with highly organized and structured lecture material, but with the highly individual forms of discovery available through research programs.

Research involvement readily accommodates all of these different student styles and expectations and is a natural extension of the educational process. For those students who may not excel in recitation or passive class work, research and participation in creative activity can provide alternative opportunities to analyze problems, to imagine new forms and processes, and to distinguish what is effective or successful from what is merely acceptable. This inherent flexibility within a research environment stimulates interest and creates new incentives for students to continue and succeed in their education. The resulting student-student and student-faculty interactions usually yield improved work habits and a tenacity for accomplishment.

At IUPUI, we offer both the environment and the attention that nurtures the success of these students as colleagues. The talent in our students cannot be wasted, and must be directed toward activities that enhance and expand their development. Research affords the opportunity to learn how to:

- formulate questions and establish premises,
- develop problem-solving strategies, and
- interpret results.

We can retain more students by providing them with exciting and challenging opportunities. Research has become a vital part of an undergraduate education that prepares students for a productive and rewarding future.

The Value of Research Experience

As reported in *Nature* (January, 1989), national studies have shown an improvement in the intellectual environment afforded by visible research programs when more available to undergraduates. Such programs have encouraged student achievement in courses. Faculty members have focused on the students' capacity to learn and placed more emphasis on student-centered learning and less on staff-centered teaching.

At IUPUI, our own studies have shown increases in student satisfaction (as measured by student course evaluations) over the last several years. This improvement coincided with dramatic

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increases in faculty research productivity over the same period. Direct economic benefits also result since research activities stimulate a broader funding base in the university, providing an increasingly important forum of student support for undergraduate assistance especially evident during periods of limited budgets.

A recent report on undergraduate research from the National Science Foundation (May, 1990) states, "The short-term impact [of research participation] is best characterized as helping the uncertain students to clarify their preferences regarding attending graduate school, field of specialization, and career path; and bolstering the certainty of the highly interested students about their initial [professional] decisions." These activities clearly enhance student retention.

Research experience also broadens students' perspectives and solidifies their desire to achieve in their careers and professions. In a recent article in the *IUPUI Facultygram* (1991), an alumna writes, "...You cannot survive in industry and go anywhere without good writing abilities. The thing that made it so easy was my work...as an undergraduate research assistant. [The faculty member] helped me through...training both in science and in writing to get an article published."

Perhaps the most telling evidence of the importance of undergraduate research is the confidence which comes from learning how to learn. Undergraduates with research experience are more experienced in focusing their work, and in applying insights learned from one course to new challenges in another.

The Role of Mentoring

Research is an intense effort that often requires a higher level of interaction between faculty and students and eventually among students. The small work group fosters a synergistic dialogue and emergence of new ideas that lead to rapid progress and that develop the "teamwork" so essential in today's workplace and civic environment.

The mentor relationship provides opportunities to evaluate results, revise expectations, and develop new perspectives. This partnership:

- provides the forum for the exchange of ideas,
- fosters the development of critical thinking skills,
- aids in understanding the intricacies of cause and effect in observations of the world around us, and
- makes clear why evidence must support conclusions.

Mentoring is an important component in research, and it is vital for establishing a proper context for independent thinking.

Many IUPUI faculty members are recognized scholars in their respective fields. They are regularly invited to present papers at professional meetings, contribute original articles to journals, and evaluate others' works and research proposals. Major research programs in progress can be enhanced by contributions from undergraduate and graduate scholars in the ways noted, but mentoring helps faculty become even better teachers as they learn from their students what methods engage and involve them in learning. Faculty members ensure the integrity of a first-class research experience and offer a sound environment for developing future scholars. One of the most exciting opportunities for mentoring often occurs when undergraduates and graduates work side-by-side on the same project under the leadership of a faculty member.

Faculty mentors want their students to achieve success and satisfaction in their chosen fields. They are available and accessible to consult with undergraduates, to counsel them, and to suggest future career and educational opportunities. Mentors know that employers value research participation highly, and that they recognize the benefits of such experience in their employees.

The success of our students in their research experience has been underscored by their participation in published research. Over the past decade

"There are so many bright students who don't know what to do to prepare for graduate or professional school. This kind of experience helps makes students aware of opportunities that can help pave the way."—*Claire Godfrey, a recent graduate, is continuing research in neurochemistry and alcohol addiction while she prepares for medical school.*

BEST COPY AVAILABLE

"IUPUI was a very conducive educational environment for me. Professors took interest in me and encouraged me to get involved in research opportunities."—*Robert Kasberg IUPUI graduate, visiting professor in anthropology*

undergraduates have co-authored hundreds of papers in professional journals.

Every year, professional meetings are held on the IUPUI campus, affording local student participation at little expense for students. These activities encourage direct contact with established researchers and teacher/scholars.

A sense of community among research students further enhances their interest in their work and studies. Community thus improves student retention and leads to a greater sense of fulfillment and satisfaction. The essential link for community, however, is based on the personal interaction of faculty with students as mentors.

Research Funding

Significant undergraduate financial support is derived from the research funding of faculty investigators, usually independent of state funding. Federal agencies, such as the National Institutes of Health, the National Endowment for the Humanities, the National Science Foundation, the Department of Energy, the National Endowment for the Arts, the Department of Education, and others, provide not only stipends to undergraduate research students, but also the funding to acquire advanced state-of-the-art instrumentation, library resources, and other research tools. Many of these instruments and resources are accessible for student research activities.

Private agencies, foundations, endowments, and corporations have numerous programs designed to provide funding to full-time faculty research programs which involve undergraduates. To encourage and foster undergraduate involvement, for example, the American Chemical Society has a specially designed grant program exclusively targeting undergraduate research. Over the past decade, IUPUI has received more funding from this particular program than any other institution in the US.

The traditional classroom and laboratory experiences are also enhanced through research activities. Often, the equipment, facilities, books, videodisks, and other material obtained from these non-university sources are used in advanced undergraduate courses. Equipment would be ordinarily unavailable through regular state funding or student fees due to the very large expense involved, and faculty research thus often provides exceptional teaching resources. As technology plays a greater role in all areas, this "side benefit" of research becomes ever more important.

Experiences Beyond the Classroom

Other more subtle consequences of research involvement go beyond the scope of ordinary course work. Researchers propose hypotheses and evaluate them based on factual or experimental data. Scholars reevaluate evidence and develop better and more compelling theories to explain events and phenomena. The nature of these evaluations is different from passive lecture material and requires new techniques of interaction and practice. Ethics and values play an important role in this analysis. Observations in any discipline require a detached and neutral point of view. Prejudice and preconception must be set aside to ensure meaningful and accurate judgments.

The influence of human and social values can also directly affect the formulation of the premises and hypotheses associated with any research project. A researcher must be careful to screen out these subjective influences or any other biases that could invalidate results and conclusions.

The perspective necessary for ensuring accuracy in data analysis and interpretation can evolve out of a close working relationship with an experienced mentor. This ethical growth does not come readily from either a textbook or a lecture, but in the real-life research scenario undergraduates learn by doing.

Epilogue

IUPUI offers diverse opportunities to students as active players in their own educational process. Students participate now in the professional activities of their futures:

- Our students are active scholars themselves: learning about, exploring, and developing new frontiers of knowledge.
- Our students, together with guidance and input from faculty mentors, shape and prepare their own futures.
- Our students experience the excitement of discovery today.

This report was prepared by an IUPUI faculty committee chaired by Professor David Malik, Department of Chemistry.

there are some very interesting philosophical reasons why it's a good one—I don't want to say it's got nothing going for it."

But van Gelder is joining others at IU in proposing that researchers start to use a framework that they believe is better. Although the computational model seems to provide a good framework for understanding some of what happens during cognitive processing, van Gelder believes that for the most part we are not anything like digital computers. He is suggesting a radical revision in the way researchers understand how the mind, brain, and body work. He says, "We have to take this whole set of conceptual tools for doing cognitive science that we've inherited from philosophy and computer science, and replace them with a fundamentally different set of tools." That fundamentally different set of tools is the mathematics of dynamical systems theory and dynamical modeling.

Dynamical modeling, or dynamics, allows researchers to track change over time, using special equations. These equations tell you how the value of one variable changes over time, depending upon the value of other variables. Researchers have used dynamics to describe everything from the planets and quantum mechanics to human metabolism.

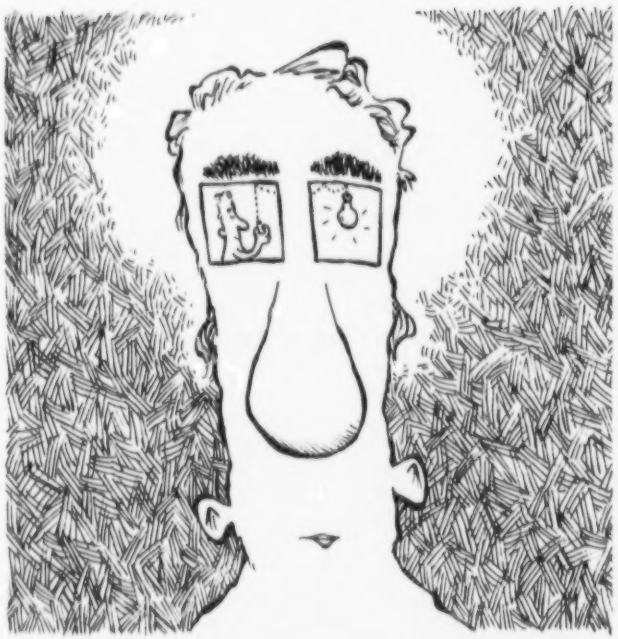
"Dynamics," say van Gelder, "is probably the most general and powerful set of mathematical tools that have ever been developed for the study of anything." And now, cognitive scientists are beginning to apply these incredibly powerful tools to the study of mind and body.

Orthodox cognitive science based on the computer model does not provide answers for questions about the boundary between the mind and the body. How do you get from what is happening in the world around you to a representation of that? How do you get from knowing what you want to do to actually getting your body to do it? "Both of these are fundamentally difficult problems," says van Gelder, "because we're using one set of tools to describe what's going on in the physical world and another set of tools to describe cognition—and they just don't fit very well." He explains, "The brain and the body have to be described in dynamic terms. There's simply no dispute there. And the argument that I would like to raise is that if we're going to understand how cognition is an embodied phenomenon, then we're going to have to use fundamentally compatible tools to describe the mind and the body."

"For the first time," he explains, "at Indiana University and a few other places, we're beginning to see how you can take this set of tools, which has been successful in so many other domains, and apply it to the study of cognition."

One project, a book that van Gelder is editing with Indiana University linguist Bob Port, testifies to the central role of researchers at Indiana. In the book, tentatively titled *Mind As Motion*, van Gelder and Port are gathering chapters from people across a wide range of fields. "We're saying, look, here is a whole new way to do cognitive science," van Gelder explains. "There are more people in that book from Indiana than from anywhere else."

In *Mind As Motion*, van Gelder is fulfilling his role as a philosopher. "All I'm trying to do is to point out that there's a pattern here," he says. "In fact there are lots of patterns.



Cartesians think of the mind as an inner entity hidden within the body and causing a person's sophisticated behavior. More recent (20C) anti-Cartesian philosophical trends see the mind primarily a matter of activity in social and physical enviroments. This activity depends, of course, on sophisticated internal cognitive processing. It is better to think of cognitive as the inner engine of mind than to think, as Descarte did, of the mind as the inner engine of behavior.

And I'm trying to understand how this fundamental shift in framework is going to affect our understanding of the nature of mind."

But the shift to the dynamical approach won't be easy, because the Cartesian picture and the computational model reinforce each other. "The dynamical approach just wasn't obvious before, partly because people were working from this basically Cartesian conception of the mind, which made the computational framework seem very attractive," he says. "There's a fundamentally nice fit between the computational model and the Cartesian conception of mind." Only when researchers break out of that Cartesian picture of mind, argues van Gelder, will they see how to apply dynamics to the study of cognition. And that transition, he believes, will provide an answer to the question at the heart of cognitive science: how do mind and body get it together?

To van Gelder, the Cartesian picture of mind and its place in nature is misguided. The picture of the mind as the engine inside our heads is too simple. "Metaphysically speaking, having a mind is much more a matter of behaving in an interesting way, than it is a matter of the internal causes that make us behave that way." How we behave depends heavily on our physical and social environments. "So that for me to have a mind is to do the kinds of things that a person does,"

he explains. "It's not merely to have some sort of complicated thing inside my head that brings it about that I do those things."

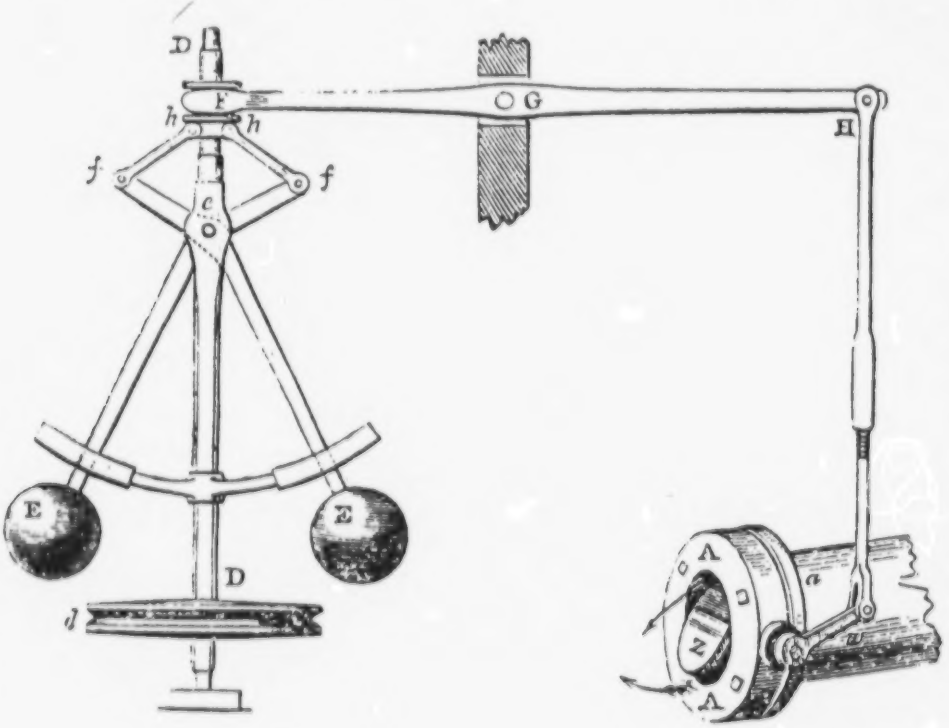
This points, van Gelder says, to a crucial mistake at the heart of the Cartesian picture, in both its old and new forms. The mind is not just a thing inside the skull that brings about actions. "If you think of cognition as all that internal, sophisticated processing that's causally responsible for my behavior," he explains, "then mind is not the same thing as cognition. It's interestingly related to it, but it's not identical with it. It is better to think of cognition as the inner engine of mind than to think of mind as the inner engine of behavior."

At Indiana University, graduate students, as well as established researchers, are learning to use the tools of dynamical modeling. Van Gelder sees a growing interest in dynamics and post-Cartesian approaches to mind among philosophy graduate students. "It's not like it's an established field in philosophy where a student is going to decide to do a dissertation," he explains. But teaching is a place for ideas to grow. Van Gelder's ideas about post-Cartesianism, for example, grew out of discussions during graduate seminars. "It's difficult to say that these are my ideas and I just happen to teach them in class," van Gelder says. "My ideas are not independent of the class and the students' ideas and what we talk about."

"Dynamics is probably the most general and powerful set of mathematical tools that have ever been developed for the study of anything."

Van Gelder believes that the shift in understanding from a Cartesian, computational approach to a post-Cartesian, dynamical one is a deep conceptual revolution. More than just an interesting new development in cognitive science, the application of dynamics provides a whole new way of understanding cognition and a new perspective on mind. And Indiana University is right at the center of this movement. "It's the first place to see in a general way that this kind of transition could happen," he says. "At IU, there's a cluster of people in different fields who are recognizing that cognitive science can use dynamical tools. And the nature of that transition needs philosophical articulation." Van Gelder is one of the first to give this transition its philosophical articulation.

—Renée Despres



A centrifugal governor for controlling the speed of a steam engine. This device exhibits very subtle interactive behavior, but it can succinctly be described by dynamicists using a differential equation. It constitutes a very different model for cognitive processes than digital computer, which dominates mainstream cognitive science.

Face Perception

While no one questions that mathematics and sciences such as physics and chemistry go together like love and marriage, mathematics and psychology are often cast as unlikely partners, if not adversaries. Psychological phenomena, the argument goes, are too complex to be expressed in mathematical equations. It is precisely that complexity, counters mathematical psychologist Jim Townsend, Rudy Professor of Psychology in the cognitive science program, that necessitates the use of mathematics.

Experimental psychologists, generally speaking, develop theories that predict and explain human behavior. For the most part, these theories have been expressed in words. Mathematical psychologists hold that this verbal form has its own pitfalls. Whereas words can be ambiguous, mathematical theorems are not open to capricious interpretation. By stating theories in mathematical form, researchers always know if their predictions follow from their basic assumptions.

In cases of competing theories, the mathematical approach has served as impartial judge. On occasion, seemingly different theories, cast as mathematical models, have proven to be equivalent.

Mathematical modeling also improves psychological testing. Predictions and results framed quantitatively are easier to compare than those in verbal form. And, not surprisingly, mathematical models help researchers to organize their theories and data in a coherent framework.

Currently, Townsend's work focuses on the establishment of a Face Cognition Laboratory within the Cognitive Science Program. "We want to study a wide range of face perception issues from the basic psychophysics of facial sensation, to more cognitive processes such as how humans learn to recognize and categorize faces," he explains. For example, elaborates Townsend, people form prototypes or stereotypes of different races or ethnic groups by abstracting certain facial features for categorization. "We hope to learn how this extremely complicated procedure is done," he says.

In the past, says Townsend, most face perception experiments relied on simplistic kinds of stimuli and experimental designs. Typically, those experiments used Identikits or Photofits to construct different faces. Identikits and Photofits are sets of drawings or photographs of various facial features, like noses, eyes and ears, which police departments use extensively in an attempt to reconstruct suspects' faces from eyewitness descriptions. Such tools are based on the assumption that faces are nothing more than a collection of individual facial features.

This approach first led researchers to view faces as a conglomerate of features, and face perception as a process that sums up the impression of individual features to yield the effect of a whole face. Findings from recent experiments, however, showed that this view is oversimplistic and misleading. The configurations of the face and the interrelation between individual features, like the distance between the nose and mouth, are at least as important as the features themselves. For example, a slight change in facial configuration can have a greater effect on face perception than the "implanting" of a totally different nose in the same face.

Jim Townsend, Rudy Professor of Psychology, Indiana University Bloomington

This oversight might explain why police composites of suspects' faces, constructed from Identikits or Photofits, according to eyewitness descriptions, are so often inaccurate. To understand the processes involved in face perception, one must consider those factors besides the features themselves, e.g., face configuration, which influence our perception of faces. For this purpose, a more realistic type of stimulus must be used.

"Real, naturalistic faces, in contrast to Identikit pictures, possess an almost infinite number of possibilities," says Townsend, adding that "they present incredible challenges in terms of theorizing." To compensate for the shortcomings of tools like Identikits or Photofits, Townsend and his researchers

Undergraduate Research:

Experiences in Creativity and Scholarly Activity at IUPUI

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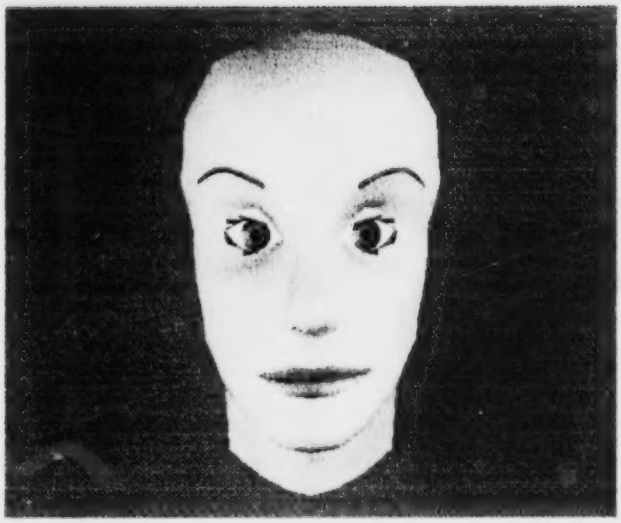
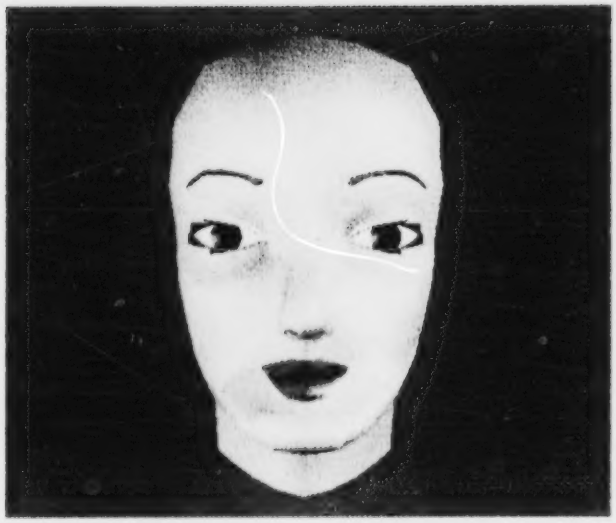
Faculty at IUPUI have recently been engaged in a two-year discussion of undergraduate education. In currently popular terminology, we are "re-engineering" general education with the goal of ensuring that our graduates can succeed in a highly complex, rapidly changing socially, economically, and technologically interdependent global environment. They must have not only the knowledge but the experiences that will permit them to grow and adapt.

One fundamental concept to emerge from these faculty discussions is the central importance of research as a necessary aspect of general education. It can become the means for personal discovery and sustained life long learning, but only if research is guided and shaped by faculty members who are partners in collaborative learning with their students. The following faculty perspective explains why research experience is likely to become one of the defining attributes of an IUPUI graduate.

William M. Plater
Executive Vice Chancellor
and Dean of the Faculties





The faces shown here demonstrate the principle of "configurationality." The face on the left with its wide narrow mouth and relatively close set eyes within a slender face tends to appear more rectangular. The face on the right is perceived as more triangular. The faces on page 21 follow the same pattern but to a less extreme degree. All aspects of the face—the size and placement of facial features such as eyes and mouth, as well as the size of the head that interacts with these features—are crucial in determining overall perception. Faces with "perceptually independent features" (not shown here) do not evoke any particular pattern in contrast to "configurational" faces. Current experiments examine how well subjects can distinguish and identify between the two categories of faces.

Townsend and graduate student Dasha Kinelovsky observe a "configurational" face which has been designed on the Silicon Graphics Personal Iris computer using software modified from Parke (1982).

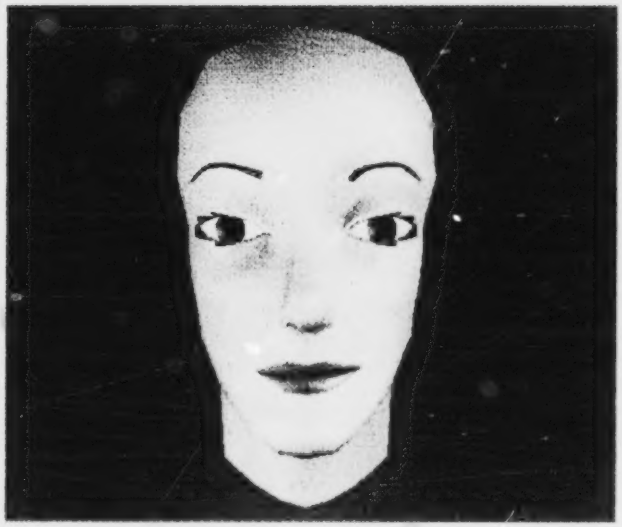
use an advanced computerized imaging system, which enable them to construct and manipulate face stimuli naturally and realistically. They are also beginning to apply global continuous types of mathematical structures (e.g., differential geometry) to replace the more unrealistic discrete models.

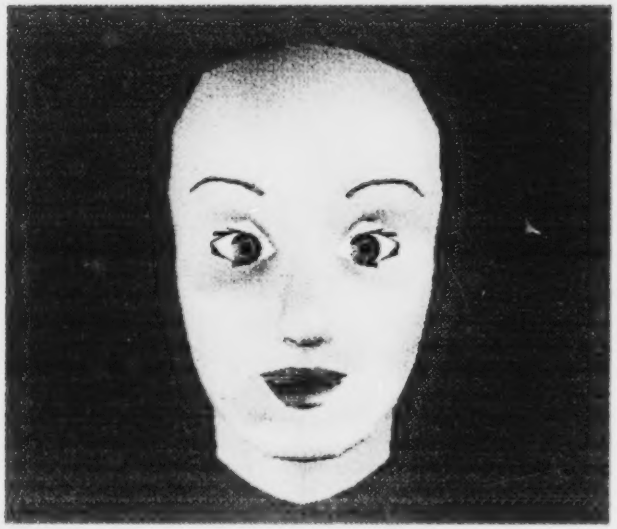
The perception of facial emotion and expression is another aspect of face perception Townsend plans to investigate in the new lab. "We will examine how to 'read' a face," he says. And, when he adds with a laugh, "This could have benign or rather insidious uses," he may be only half-joking. With a little imagination, one can picture wide ranging situations—like in the courtroom, business meeting, or bedroom—where face reading would be decisive.

While an increasing number of researchers have studied face perception over the last twenty years, little mathematical modeling has been done in that area. Townsend will be one of the first to construct these challenging models, which must be both complex and "ecologically valid," or descriptive of processes operating in realistic, everyday situations. Ultimately, his work could have applications to security, law enforcement, and the legal system.

Jim Townsend is one of only a small, but growing, group of mathematical psychologists in the country. While most mathematical psychologists arrived to their field by way of mathematics, Townsend entered through the back door. A clinical psychology student at Fresno State College in the mid-1950s, Townsend gradually found himself drawn to experimental psychology. "I started to feel that one could most help the overall discipline and its applied areas by doing basic kinds of research," he says.

Introduced to the infant field of mathematical psychology





by a forward-thinking professor, Benjamin Burton, Townsend saw "a world of possibilities" open before him. "I realized that mathematics, being one of the most essential tools of science could also be of tremendous use to psychology." He started supplementing his "skimpy" mathematics background, and finally earned a minor undergraduate degree in that subject.

By the time Townsend completed his B.A., he had decided to pursue graduate studies in mathematical psychology. Accepted to a doctoral program in psychology at Stanford University, Townsend specialized in mathematical psychology and the emerging field of cognitive science.

At Stanford University, Townsend fell under the wing of two of the founders of mathematical psychology, former IU Professor, William K. Estes, and Richard C. Atkinson, an I.U. alumnus who directed the National Science Foundation for several years. There, Townsend took courses in mathematical learning theory and graduate psychology disciplines, as well as in mathematics, statistics, and electrical engineering. He also began to carry out research in visual perception and memory.

After receiving his doctorate at Stanford in 1966, Townsend joined the faculty at the University of Hawaii for two years. Relinquishing scuba diving and surfing to come to Indiana in 1968, Townsend joined the Purdue University faculty as an assistant professor in its Department of Psychological Sciences. For the next 21 years, he explored various fields of Cognitive Science, and gained international attention for his pioneering work in the area of parallel vs. serial processing.

Attracted by what he calls "IUB's rich history in mathematical psychology" even at that relatively early stage, Townsend moved to the Bloomington Department of Psychology in 1989. Two luminaries in the field, Frank Restle, who has since passed away, and James Greeno, now at Stanford University, had been psychology professors during the 1950s, and had helped develop mathematical learning theory. They helped lay the groundwork for much of the research that was to come in mathematical psychology.

During the last two and a half decades, Townsend's research has explored a wide range of areas covered by the Cognitive Science umbrella: visual pattern recognition, face perception, memory, categorization, and decision making, all from the exacting viewpoint of a mathematical psychologist.

Like many other cognitive scientists, Townsend views the brain as an information processing machine whose input is the vast array of stimuli surrounding us, and whose output is behavior. As the precise internal construction of this extremely complex "machine" is largely unknown, scientists have developed different techniques to reveal its inner workings. While neurobiologists study the physical composition and processes involved in brain function, cognitive psychologists view the brain as a "black box." They try to uncover its "mental architecture" through experimentation that involves manipulating input and examining the resulting output. "This kind of 'black box' theorizing," says Townsend, "is crucial to learning more about human cognition and emotion."

Ongoing research on the question of serial vs. parallel processing has incorporated this approach. This debate, which can be traced to the beginnings of psychology over a century ago, concerns whether humans perform certain processes in a strictly sequential (serial) or parallel (simultaneous) way.

Consider, for example, the sentence you are now reading. While the meaning of each word seems to pop into your mind automatically, an involved process is taking place. How exactly do we identify words? Do we read and identify each letter at a time before we can understand a word's meaning, or do we process all letters simultaneously, in a more holistic process of understanding?

This central problem of serial vs. parallel processing is one of the oldest in psychology, dating back to the mid-nineteenth century. In 1859, the Scottish psychologist William Hamilton tried to solve this problem by tossing several dice on his desk and trying to assess 'instantaneously' the number of dots showing. He was, in effect, trying to determine the number of objects that could be apprehended simultaneously (i.e., in parallel) by human consciousness. "This subject has

FOR CRYING OUT LOUD, HENRY, THIS PLAY IS BORING AND MISERABLE... WHY DON'T WE JUST GO HOME..?
...BECAUSE AT FIFTY BUCKS A TICKET, WE'RE GOING TO BE BORED AND MISERABLE AND LIKE IT, BY GAWD...
GOVERY!

The irrationality of human decision making

reappeared in different guises in the emerging psychological laboratories of the world," says Townsend. "It is still a lively research topic today in diverse areas of pure and applied cognitive psychology. The longevity of the topic is probably due to its fundamental importance in describing how mental operations take place."

Early in his career, during the 1960s, Jim Townsend challenged the widely held belief that human information processing was sequential in nature. "Some of my first studies showed there were parallel systems that perfectly mimicked serial systems," says Townsend, whose theory first met with opposition, and then was accepted by the psychological community. Later, he pointed out that while parallel and serial mechanisms often appear indistinguishable, what he calls the "Tweedledee and Tweedledum" syndrome, they can indeed be told apart by proper experimentation.

Townsend concedes that the parallel/serial question may not be resolved by mathematical work alone. He asserts, however, that mathematics aids the development of experimental designs that can decisively test such hypotheses.

Along somewhat different lines, Townsend, and his colleague, Jerome Busemeyer of Purdue University, reacted against a whole tradition in psychological research by introducing dynamic mathematical models into the study of decision making beginning in 1984. Classical decision-making theory stemmed from von Neumann and Morgenstern's 1944 utility theory of economics. In essence, this theory assumed that people's decisions follow a rational model leading to optimal rules. It has become clear, however, that really human decisions, which are often irrational and inconsistent, violate these rules and deviate from the traditional theories.

In their lives, people do not always make the optimal choice. Past theories ignored the non-optimal nature of people making day-to-day decisions and yielded unrealistic predictions. These theories, according to Townsend, were static, and unconnected with traditional knowledge of psychology. "A good psychological theory must incorporate known facts about human cognition and emotion, so that predictions will follow naturally," he says.

One way to demonstrate the irrationality or inconsistency of human decision making is to show how the same information presented in different forms can lead to different decisions. Imagine that you are watching a play after having paid $10 or $50 for a ticket. Suppose you are not enjoying the play. Does whether or not you walk out depend on whether you paid $50 or $10? Logically it shouldn't. You've paid and your ticket is nonrefundable. Your only concern should be how you wish to spend your time. Most of us, though, would be more likely to sit through a play, however poor, that cost $50 rather than $10.

Illogically, such "sunk costs," which should not influence our future choices, usually do.

Another important aspect of decision making not considered by other theories, says Townsend, is the "gravity-like" effect. With proximity, positive attraction to a choice object (e.g., a piece of candy) increases. Similarly, if the object also has unpleasant aspects (e.g., it makes one fat), the negative attraction (i.e., repulsion) also becomes greater with closeness. Townsend's models incorporate this, and other knowledge gleaned from human motivation research, to create more realistic models.

Mathematically, these models attempt to describe the real behavior of people in real situations. Besides their importance in decision making, the models represent some of today's most progressive work in modeling cognitive processes through a dynamic systems approach.

Looking ahead, Townsend plans to expand the use of mathematical models in the study of human information processing. While mathematics has been employed extensively in this area, especially regarding reaction time and response accuracy in experiments, it usually involved non-rigorous and unsophisticated techniques. As a result, "No global theory exists today that is capable of predicting accuracy and response times ranging from low-level accuracy to perfect performance," says Townsend, who is now working closely with his students to develop such a theory, and ultimately apply it to face perception.

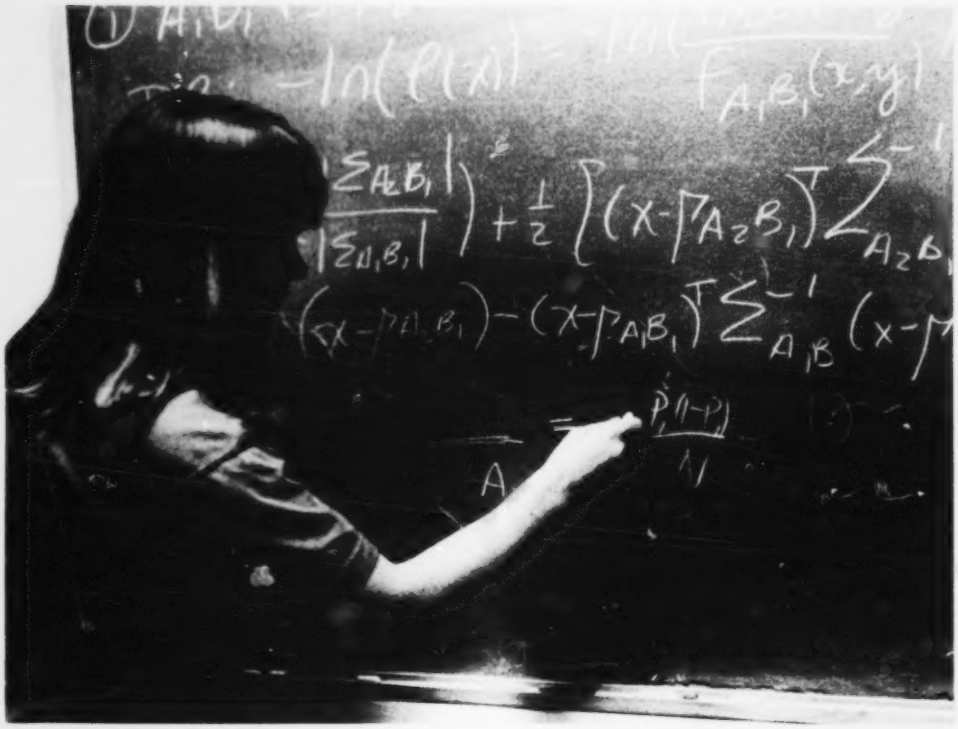
Townsend terms his students, "the next generation of scientists" and his role with them, "a mission." "Basically, all my graduate students become mathematical modeling theorists by the time they get their degrees," he says. "This is extremely important because in the foreseeable future, there won't be many people trained for this work. It is incumbent on the few of us who work in mathematical psychology, to make sure that those in our labs not only write papers, but are trained as top-notch scientists."

This past year, a National Institute of Health grant boosted Townsend's "mission." A grant from the National Institutes of Mental Health on "Models of Cognition" awarded to the Mathematical Psychology Group of the Program of Cognitive Science has enabled both pre-doctoral and postdoctoral students to study mathematical psychology here at IU. Along with the University of California at Irvine, IU is the country's leading center for research and training in this area.

Townsend's past students have pursued careers in academia or in industry. According to Townsend, their training makes them valuable in such research areas as human factors and human engineering, since their mathematical background allows for the easy—and necessary—communication with engineers and physicists.

Jim Townsend's work proves that like physics, biology, or chemistry, human behavior can be couched in quantitative terms, and precisely measured and studied. Mathematics, according to Townsend, is not just another tool for psychologists, but the vehicle that will move the field forward. As he puts it, "Mathematical work, when directed toward specific psychological questions or problems, has led to and will continue to lead to some of the most critical advances in psychology."

—Roberta Neiger



Graduate student Robin Thomas at the blackboard working on an equation. Such mathematical modeling is the cornerstone of research in mathematical psychology.

The Power of Abstraction in Problem Solving

Josh Tenenberg, Assistant Professor of Computer Sciences at Indiana University South Bend

In the Charlie Chaplin film *Modern Times*, there is a classic scene of Chaplin working in a factory. He is an automaton, working without thinking, as he tightens this and screws down that. Things are always presented to him in a predictable manner—same rate, same orientation. His world is orderly and predictable until he misses a piece and has to play catchup. He then rushes from his station, bumping into co-workers, and even climbing up on the line so that eventually his buttons get tightened. His world becomes disordered.

Order and disorder: the words can apply to the world's political situation, the country's finances, or your sock drawer. When concerning the world of computers, they take on very specific meanings. Computer programs define a set and orderly world. Tasks are limited and well defined. There is no disorder, but neither is there flexibility. If the parameters are not met exactly, the task is not completed. These circumstances are the challenges facing researchers of artificial intelligence: finding ways for computers to work in a disorderly environment, for computers to "think." Dr. Josh Tenenberg, currently an assistant professor at Indiana University South Bend, has been working on these issues in artificial intelligence in graduate school and for the past four years as a research scientist.

All computer programming, no matter what language is used, is based on mathematical theories and algorithms. Artificial intelligence is concerned with the development of mathematical algorithms to program a computer to execute all the steps that make up what we call reasoning. These algorithms will allow a computer to form abstractions, make analogies, and draw generalizations, as well as put together a collection of data and inductively arrive at the best way of operating. Artificial intelligence is programming computers to solve problems.

This is not as straightforward as it seems, for the programmer must deal within the limitations of the

computer's resources. Even the simplest problem-solving program takes an inordinate amount of time to be processed by the computer. And as the complexities of these programs increase, the issue of space becomes a constraint: both the space available to store the program and the RAM space needed to run the program. These constraints are the area in which Tenenberg has chosen to focus. He is trying to reduce the computational complexity of computer problem solving, thereby using less time and space.

"There are so many things involved in solving a problem," Tenenberg explains. "Hypothetical reasoning. Sequential planning. Prioritizing. We humans have such a rich representation of the world in our heads that allows us to predict and plan. The challenge is to arrive at formulas that would allow a computer to do the same thing, but quickly and using a reasonable amount of its storage capability."

To further explain what he is trying to accomplish, Tenenberg poses the problem of driving across the country to visit his mother in Oakland, California. One possible method to solve this problem would be to jump in the car and head west, stopping occasionally to see if he saw her house. There would be very little computation involved, but total execution time might be quite lengthy.

Another method might be to study maps and plan out a route. This method would take a greater investment of effort and time in planning, but it should cut down the execution time greatly. In fact, the map is a representation of the route and he could mentally drive a variety of ways, trying to hypothesize about the outcome of each of them. Routes that would take him far out of his way could be eliminated much faster than they could be physically explored. Thus, he can choose the best route before setting foot in the car. He saves considerable time by planning, that is, mentally searching a representation of the problem.

Using robots or any type of automated agent to plan the kinds of problems they might solve was not Tenenberg's original idea. "It has been kicked around seriously for the last 40 years," Tenenberg says. "People like John McCarthy and Nils Nilsson at Stanford, and Alan Newell and Herb Simon at Carnegie Mellon, are just a few of the people who did the early work. The key idea of planning is that you need some mental representation of the world in which the robot is going to be operating, so that you can think about the world, rather than just place the robot in this world and hope good things happen when it starts flailing its arms and legs about. Usually, good things don't happen randomly: one must carefully plan the order in which things are done to get things to work out just right."

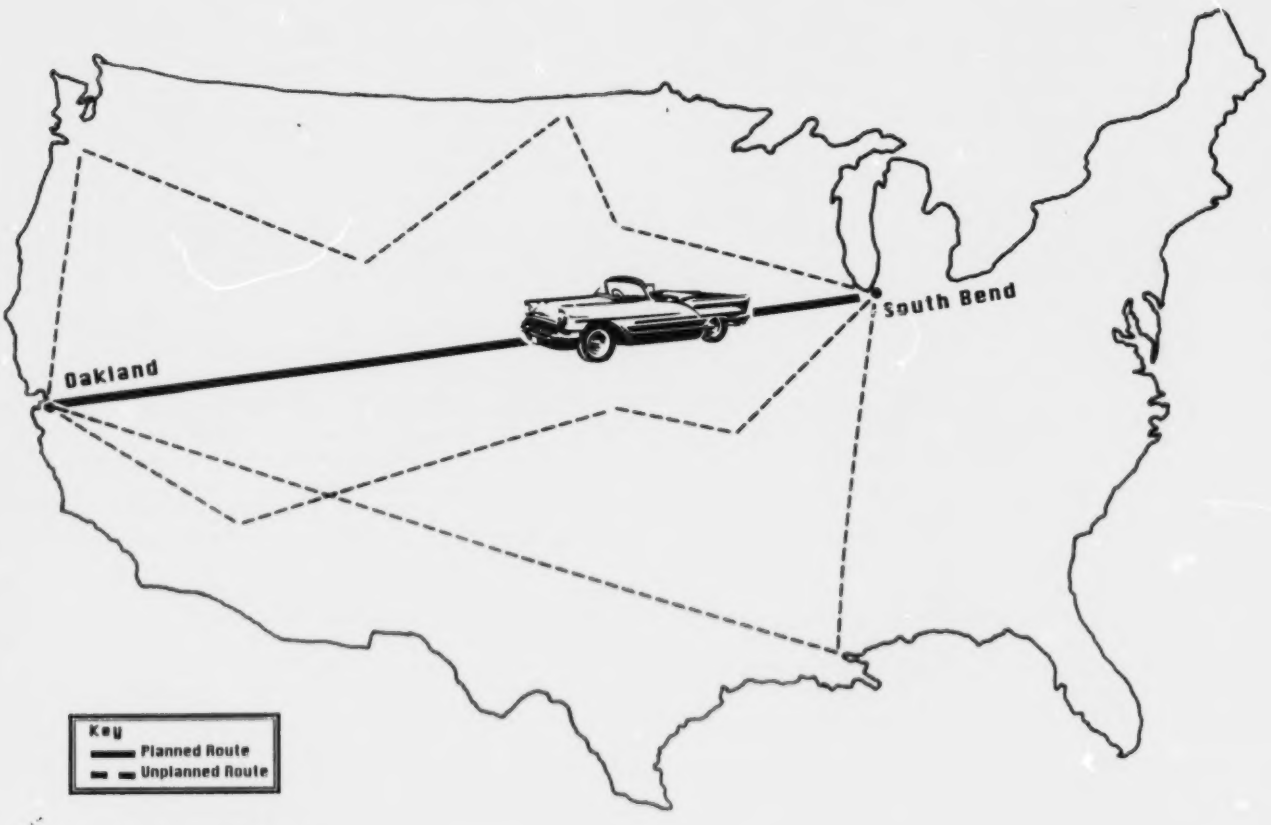
Unfortunately, the process of giving the computer the information it needs is an extremely difficult problem. Not much is known about how people store data in their brains and how they address problems. In fact, some people in artificial intelligence feel that thinking is no more than a reaction to a stimuli, a very simple process requiring only basic data. Others, including Tenenberg, feel that humans do have a capacity for deep reasoning and inference, and that much can be learned about how to equip computers to solve problems by studying the way humans do.

By trying to reduce the computational complexity of planning, Tenenberg is constantly challenged to understand human reasoning. The mental map that worked so well for a human in planning a drive across the country does not work nearly as well for a computer. Driving a mental car around on a mental map might work well for humans, but when a computer does it, there are just too many possibilities. There are a dozen choices at each juncture, thousands of possible routes. The mental car might be faster than actual physical driving, but it would not be very efficient. There must be a better way.

Tenenberg has tried to formalize a notion of abstraction. "I want the computer to ignore some details in the mental map," he explains. "There'll be fewer decisions to make, but each of these decisions is important in the sense that if it makes them, it would have a rough plan for getting to its destination."

One way to do this is to ignore all secondary and tertiary roads, and only look at interstates, and plan the trip using just interstate roads. Now the task of getting to Oakland is much simpler; there are fewer choices to make, and fewer roads from which to choose. After that the plan can be refined by choosing smaller roads to fill any gaps that might remain.

It sounds straight forward to our minds, but just how does Tenenberg go about



The most direct route: as the car drives.

programming a computer to do this? In a "mathematically precise way," he tells the computer how to abstract out the "details," how to solve the problem with the abstracted representation, and how to take this abstract solution and use it as a guide to solve the original problem; thus, he can show mathematically how these instructions can lead to fewer computational resources being expended in planning.

Tenenberg asserts that "In terms of my concrete route planning example, this would mean proving that by using only interstates, one can always find a path between any two geographical regions, that this path will be no larger than a path that includes secondary and tertiary roads between the two actual locations, that a path between the two actual locations can be obtained from the interstate path by simply adding in secondary and tertiary roads, but never having to detour or backtrack from the interstates."

Though computers and problem solving consume a large part of Tenenberg's time now, it was hardly his lifelong goal. He grew up in the San Francisco bay area and graduated in 1980, with a bachelor's (summa cum laude) degree in music from San Francisco State University. His goal was to be a classical musician playing the trumpet. Once he reached his goal, Tenenberg had second thoughts. He admittedly hated practice and got nervous in concerts. He loved music, but was not sure about taking it on as a job, so he took some time off after graduation to "air out his brain." He worked as a waiter, played his trumpet, and did some contract programming work.

From all these experiences, he arrived at a solid understanding of who he was and what he wanted to do. He liked interacting with people, enjoyed teaching, and preferred mathematical kinds of things and problem solving. One book that sharply piqued his interest was *Godel, Escher and Bach: An Eternal Golden Braid* by Indiana University professor Douglas R. Hofstadter.

Once he decided on artificial intelligence as his career path, Tenenberg attended the University of Rochester, receiving his Ph.D. in 1988. He stayed there for another four years doing research and teaching before coming to Indiana University South Bend as an Assistant Professor in the Department of Mathematics and Computer Science in 1992.

Scientists in their experiments are always abstracting details, saying friction does not matter or temperature should be ignored. It is their way of holding things constant, just as we ignore background noise or the traffic flow in the hallway

From Inquiry to Publication: *Books by Indiana University Faculty Members*

Aman, Alfred C., Jr. *Administrative Law and Process.* New York: Matthew Bender Company, 1993, 978 pp., $43.95, cloth.

This book is about power and principles. It addresses the law governing the means by which executive, legislative, and judicial power are exercised as well as allocated to, among, and within the various governmental entities called administrative agencies. The exercise of this power occurs in accord with, and sometimes despite, certain legal rules, principles, and processes. It is these rules, principles, and processes that form the primary subject matter of this book. They are examined in context by linking the issues and conflicts that are generated to some of the broader societal issues of our times. Aman is Professor of Law and Dean of the School of Law at IUB.

Bondanella, Peter. *The Films of Roberto Rossellini.* New York: Cambridge University Press, 1993, 183pp., $14.95, paper.

Tracing the career of one of the most influential Italian filmmakers, this work analyzes the seven films that mark important turning points in Rossellini's evolution: *The Man with a Cross* (1943), *Open City* (1945), *Paisan* (1946), *The Machine to Kill Bad People* (1948-52), *Voyage in Italy* (1953), *General Della Rovere* (1959), and *The Rise to Power of Louis XIV* (1966). In addition it explores in depth the aesthetic dimensions of his working method. Bondanella is Professor of Film Studies and Italian, Chairperson of West European Studies, and Distinguished Professor of Comparative Literature at IUB.

Bradley, Craig M. *The Failure of the Criminal Procedure Revolution.* Philadelphia: University of Pennsylvania Press, 1993, 290 pp., $32.95, cloth.

The United States should, in keeping with the international trend, regulate police procedures through a comprehensive and nationally applicable code. Bradley reexamines why the present system is a failure and how other countries have developed their criminal procedure law. He further argues that a national code would be constitutional and outlines what its features should be, how it would function, and what alternative approaches are possible and practicable. Bradley is Professor of Law at IUB.

Brandewie, Ernest. *When Giants Walked the Earth: The Life and Times of Wilhelm Schmidt SVD.* Fribourge, Switzerland: University Press, 1990, 357 pp., 58.00 swiss francs, cloth.

The diversity of Wilhelm Schmidt (1868-1954), an ethnologist associated with culture circles, is emphasized in this biography. Brandewie is Professor of Anthropology at IUSB.

Bull, Barry T., Fruehling, Royal T., and Chattergy, Virgie. *The Ethics of Multicultural and Bilingual Education.* New York: Teachers College Press, 1992, 224 pp., $18.95, paper.

This work offers readers an introduction to the ethical problems arising from cultural and linguistic differences among students, professional educators, and parents in school settings. It also demonstrates and assesses the application of three different theories of political morality—Liberal, Democratics, and Communitarian—that offer analytical approaches to solving these problems. Bull is Associate Professor of Education and Director of the Center on Policy Studies in the School of Education at IUB.

Cherry, Conrad, and Sherrill, Rowland, eds. *Religion, the Independent Sector, and American Culture.* Atlanta: Scholars Press, 1992, 355 pp., $19.95, paper.

Neither a part of government nor commerce, religious voluntarism, as a component of the American third or independent sector of culture, has sought to adopt the forms and strategies of social influence without losing its distinctive identity and contribution. Essays on the intersection of religion and culture in the areas of Catholic charities, higher education, hospital ethics committees, and public policy are included, along with contributions on the Pastoral Care Movement and the tax exempt status of churches and charities. Conrad is Distinguished Professor of Religious Studies and Director of the Project on Religion and American Culture at IUPUI and Sherrill is Professor of Religious Studies and Chairperson of the Department of Religious Studies at IUPUI.

Clausen, Jeannette, and Friedrichsmeyer, Sara, eds. *Women in German Yearbook 8: Feminist Studies in German Literature and Culture.* Lincoln, Nebraska: University of Nebraska Press, 1993, 262 pp., $12.95, paper.

The selections span German literary history from the Middle Ages to the present and treat canonical as well as noncanonical literature, popular as well as "high" culture, male as well as female authors—and a correspondingly diverse array of generic forms. The volume includes a wide range of feminist critical approaches, as well as highlights some of the ways in the articles resonate accordantly or discordantly with each other and thus reflect ongoing dialogue as well as incipient debates among feminist Germanists. Clausen is Associate Professor of Germanic Languages and Director of Women's Studies at IUPUFW.

"We humans have such a rich representation of the world in our heads that allows us to predict and plan. The challenge is to arrive at formulas that would allow a computer to do the same thing, but quickly and using a reasonable amount of storage capability."

as we work. Tenenberg's challenge is to understand this process. How can he program a robot to decide which details to ignore and which to process? Even more challenging is the idea of a program that allows these details to be ignored sometimes and noticed other times.

One would expect Tenenberg to be surrounded by computers and robots. Tenenberg's research, however, is done with paper and pencil as he mathematically defines some form of abstraction and tries to prove theorems. Mathematics, set theory, logic, induction, and formal theories of knowledge representation that have developed over the last 40 years in the cognitive sciences are his tools. To test the problem-solving ability of his programs, he uses a program to solve a number of different problems, then compares the results to systems that do not use abstraction. It is an imperfect way to test theories, but he cannot simply turn a robot loose in a real environment and take measurements. He has chosen to ignore too many real complexities, so the tests must be done in simulated worlds.

"This is true of much of the work in artificial intelligence," he says. "People in the field are still figuring out how to adequately test their theories. In fact, this is true of the entire field of computing. When do you know that your computer program embodies your model of a problem situation and a solution?"

Uncertainty is familiar to those writing computer programs and probably always will be. Tenenberg, however, believes his more formal approach eliminates some of it and that formal rigor *is* a defensible methodology. He says, "One might not like *what* I am formalizing, or how. But these are really the only things to argue about: proofs are proofs! Those we don't argue about."

"A point of contention is that people might say: well, definitions do not seem to capture an important principle, or, your results are not sufficiently applicable," Tenenberg says. "But by being very precise about what I'm saying, I allow people to be very precise about what they don't like. And I believe this is a reasonable way for science to happen."

So far Tenenberg's research has helped him reach some conclusions. He continues to believe that abstraction is an extremely powerful problem-solving technique and feels that his research has shown that there are several kinds of abstraction. Each of these kinds requires different mental search strategies to be effective. The difficulties arise in trying to integrate the various kinds of abstraction into a single problem-solving system, and then showing this system is superior to one that does not use abstraction.

Due to the lack of a graduate program in computer science at IUSB, students are not actively involved in Tenenberg's research, though one of his students just received an Undergraduate Research Fund award for research on neural networks with Tenenberg named as faculty mentor. It usually takes several years of graduate study to achieve the background necessary to do even the most rudimentary research in artificial intelligence, though Tenenberg hopes that his research evolves in a way as to involve students more. Yet his research and teaching at IUSB are in good balance, each undertaking feeding and enhancing the other. Years of research activity in the field of Artificial Intelligence have forced Tenenberg to precisely define the elements that make up thinking and learning. As he works with students, he can see how they are using these elements, which elements should be strengthened, and where restructuring or backtracking is necessary. He understands that making mistakes is a fundamental part of learning. Most of all, he understands that each student has been imprinted in his or her own unique way, so that each individual's path to truth will indeed be different.

—Anne and Ed Kolaczyk

Davis, Thomas J. *The Clearest Promises of God: The Development of Calvin's Eucharistic Teaching*. New York: AMS Press, 1993, 239 pp., $39.50, cloth.

This work provides a detailed analysis of the development of Calvin's eucharistic doctrine. In doing so, it demonstrates the importance of examining the full range of Calvin's writings and dispels the notion that one need look only at the 1559 *Institutes* to grasp Calvin's eucharistic theology. The author pinpoints the doctrine as the work of the Holy Spirit in the Eucharist, accommodation, instrumentality, and the Eucharist as a means of grace, as well as demonstrating that there are eucharistic gifts according to Calvin. Davis is Assistant Professor of Religious Studies at IUPUI.

Gibson, Robert L., Mitchell, Marianne H , and Basile, Sherry K. *Counseling in the Elementary School: A Comprehensive Approach*. Boston: Allyn and Bacon, 1993, 372 pp., $45.00, cloth.

Designed to introduce readers to the role and practice of counseling services in the elementary school, this book can be used in introductory counseling courses and in related fields for those who seek a comprehensive overview of counseling services in the elementary school. It also provides an overview and general understanding of: 1) foundations and a rationale for counseling activities in the elementary school; 2) techniques utilized by counselors; 3) the organization of counseling programs; and 4) legal and ethical guidelines. Gibson is Professor Emeritus of Education at IUB and Mitchell is Professor of Education at IUB.

Glass, Don, ed. *Why You Can Never Get to the End of the Rainbow and Other Moments of Science*. Bloomington: Indiana University Press, 1993, 165 pp., $10.95, paper.

Understandable, entertaining answers to more than one hundred everyday mysteries of science, including questions on mathematics, botany, biology, physics, meteorology, astronomy, chemistry, and more are given. The short essays contained in the book are adapted from the scripts for the syndicated public radio series *A Moment of Science*. Glass is Director of Special Projects for the Radio and Television Services at IUB.

Goodman, Jesse. *Elementary Schooling for Critical Democracy*. Albany, New York: State University of New York Press, 1992, 211 pp., $12.95, paper.

This book examines the way in which elementary schooling can be used as a means to encourage critical democracy in the United States. It focuses primarily on the dialectical tensions and issues that emerge from the conflicting values of individuality and community through a portrayal of an independent elementary school committed to democratic education. Goodman is Associate Professor of Education at IUB.

Jackson, William J. *J. L. Mehta on Heidegger, Hermeneutics and Indian Tradition*. Kinderhook, New York: E. J. Brill USA Inc., 1992, 300 pp., $91.50, cloth.

The author presents a selection of essays by the Indian philosopher J. L. Mehta on the topics of hermeneutics and phenomenology containing many original reflections on questions of interpretation and the creative retrieval and renewal of meanings fror ncient traditions. Beginning with essays on sources of modern phenomenological methods, the work goes on to articulate principles of phenomenology and to apply them to the interpretation of Hindu traditions and texts. The final group of essays consider the problems of East-West understanding and issues of intercultural relationships and the possibilities of planetary thinking. Jackson is Associate Professor of Religous Studies at IUPUI.

Klotman, Phyllis Rauch, ed. *Screenplays of the African American Experience*. Bloomington: Indiana University Press, 1993, 265 pp., $14.95, paper.

An introduction to two decades of independent black filmmaking, this collection of six screenplays included in this anthology were written and produced between 1973 and 1989, and represent a sample of the best narrative, short, and feature films made in the United States by African Americans during this period. All depict some aspect of black experience scarcely if ever touched upon in Hollywood productions. Klotman is Professor of Afro-American Studies and Dean of the Office for Women's Affairs at IUB.

Mann, Coramae Richey. *Unequal Justice: A Question of Color*. Bloomington: Indiana University Press, 1993, 301 pp., $14.95, paper.

The author clearly establishes that African Americans, Native Americans, Hispanic Americans, and Asian Americans do *not* receive equal treatment from the U.S. criminal justice system. And it is not only because they are unemployed, poor, frustrated, and lack non-criminal role models—although these are all contributing factors. The common thread that ties the criminality of these groups together is their skin color. Mann is Professor of Criminal Justice at IUB.

May, Larry, and Strikwerda, Robert A., eds. *Rethinking Masculinity: Philosophical Explorations in Light of Feminism*. Savage Maryland: Rowman & Littlefield Publishers, 1992, 256 pp., $12.95 paper.

Together the twelve essays by male philosophers sympathetic to feminism approach the variety of experiences of being a male in Western culture. This attempt is an effort to provide reasonable analyses of what is wrong with the traditional model of masculinity and to offer plausible suggestions for change that will redefine the roles men can play as nurturers, as intimates, and as partners in today's world. Strikwerda is Assistant Professor of Philosophy at IUK.

McCormick, John. *Reclaiming Paradise: The Global Environmental Movement.* Bloomington: Indiana University Press, 1989, 259 pp., $12.50, paper.

This book goes beyond the many studies of national movements and looks at the rise of environmentalism as a global phenomenon. Beginning with the protection and conversation movements of the nineteenth century, the author takes the story through the mass movements of the 1960s and 1970s and beyond. Key events in recent environmental history are presented, and issues ranging from the significance of the Stockholm conference of 1972, to the rise of the Greens, to the debate over acid rain, the ozone layer, and the greenhouse effect are explored. McCormick is Assistant Professor of Political Science at IUPUI.

McDonald, Ralph E., and Avery, David R., eds. *Dentistry for the Child and Adolescent.* Fifth Edition. St. Louis, Missouri: The C. V. Mosby Company, 1988, 937 pp., $54.95, cloth.

The fifth edition of this book provides current diagnostic and treatment recommendations based on research, clinical experience, and current literature. The information is relevant to the practice of pediatric dentistry and is designed to help undergraduate dental students and postdoctoral pediatric dentistry students provide efficient and superior comprehensive oral health care for infants, children, and teenagers. McDonald is Professor Emeritus of Pedodontics and Dean Emeritus of the School of Denistry at IUPUI and Avery is Professor of Pediatric Denistry and Chairperson of the Department of Pediatric Denistry at IUPUI.

McGregor, Eugene B., Jr. *Strategic Management of Human Knowledge, Skills, and Abilities.* San Francisco: Jossey-Bass Inc., Publishers, 1991, 320 pp., $35.95, cloth.

The author offers sophisticated techniques for assessing workforce roles and capabilities, and he explores the fundamental strategic and tactical choices that public sector managers must face—about organization design, compensation plans, production technologies, budgeting, and more—in order to make productive personnel allocations and so meet policy and planning goals. McGregor is Professor of Public and Environmental Affairs at IUB.

Mickel, Emanuel J., Jr., ed. *The Shaping of Text: Style, Imagery and Structure in French Literature, Essays in Honor of John Porter Houston.* Cranbury, New Jersey: Bucknell University Press, 1993, 168 pp., $27.50, cloth.

The essays in this volume pay homage to the work of the late John Porter Houston, who wrote extensively on style, rhetoric, and narrative, and poetic techniques in Western European literature. The essays focus on the form of the literary work and the ways in which form determines meaning. Mickel is Professor of French and Chairperson of the Department of French and Italian at IUB.

Misztal, Bronislaw, and Shupe, Anson. *Religion and Politics in Comparative Perspective Revival of Religious Fundamentalism in East and West.* Westport, Connecticut: Praeger Publishers, 1993, 240 pp., $45.00, cloth.

The authors bring together theoretical and empirical studies that focus on fundamentalist social movements in North and Central America and Eastern Europe and that examine the role religion plays in determining the direction of social evolution. Each chapter emphasizes a common set of processes at work: how religious identities arise or reemerge to confront the globalization trend, how various social movements cope with pressure to conform their identities, and how the globalization trend sets in motion the antithetical reaction of the nationalistic/religious dialectic that it was thought to have eliminated. Misztal is Professor of Sociology at IUPUFW and Shupe is Professor of Sociology at IUPUFW.

Pepinsky, Harold E., and Quinney, Richard, eds. *Criminology as Peacemaking.* Bloomington: Indiana University Press, 1991, 339 pp., $17.50, paper.

The essays in this volume propose peacemaking as an effective alternative to the "war" on crime. They range from studies of the intellectual roots of the peacemaking tradition to concrete examples of peacemaking in the community, with special attention to feminist peacemaking traditions and women's experience. Pepinsky is Professor of Criminal Justice and East Asian Languages and Cultures at IUB.

Schick, Kathy D., and Toth, Nicholas. *Making Silent Stones Speak: Human Evolution and the Dawn of Technology.* New York: Simon and Schuster, 1993, 351 pp., $25.00, cloth.

By drawing on two decades of field work around the world, the authors show how early prehistoric sites have been discovered, excavated, studied, and interpreted. In an effort to reconstruct the lives of our primitive tool-making ancestors, the authors take the readers along with them to the savannahs of East Africa, the plains of northern China, and the mountains of New Guinea—and into the past. Then, in an a dramatic recreation of primitive technology, they show how early stone tools were made—and how they can be made and used today, by both modern human beings and chimpanzees. Schick is Assistant Professor of Anthropology at IUB and Toth is Associate Professor of Anthropology at IUB. Both are Co-Directors of the Center for Research into Anthropological Foundations of Technology at IUB.

Schlegel, Kip, and Weisburd, David, eds. *White-Collar Crime Reconsidered*. Boston: Northeastern University Press, 1992, 384 pp., $45.00, cloth.

New writings both on the theoretical issues of the causes of white-collar crime and on the problematic issues surrounding its social control by the criminal justice system and other agencies are presented. Essays on definition and theory, victimization, enforcement, and the sanctioning of organizations and individuals raise important questions, ranging from what sanctions against corporate criminals a society can enforce, to the debate over whether many white-collar offenders can even be prosecuted, given the fact that their activities are often camouflaged as legitimate business practices. Schlegel is Assistant Professor of Criminal Justice at IUB.

Shermis, Mark., *et al. Using Microcomputers in Social Science Research*. Boston: Allyn and Bacon, 1991, 224 pp., $24.95, paper.

This volume shows how microcomputer technology can be applied to social science research in psychology, education, sociology, political science, health sciences, and information science. Using a research cycle this book offers examples of research studies from conceptualization through dissemination and shows where microcomputer applications fit into methods and procedures. It also introduces business applications that researchers can use to make effective grant applications. Shermis is Associate Professor of Psychology and Director of Testing, Planning, and Institutional Improvement at IUPUI.

Smith, Carl B. *Intermediate Grammar: A Student's Resource Book*. Bloomington: Grayson Bernard Publishers, 1993, 306 pp., $16.95, paper.

Designed to answer questions and to polish the writing process for middle and high school students, this reference book explains the complicated rules of grammar and sentence structure. It also includes explanations and definitions in language students will understand, examples taken from actual student writing to focus on common questions and errors, exercises for children to check their understanding, and a punctuation guide at the end of the book. Smith is Professor of Education and Director of the ERIC Clearinghouse on Reading and Communication Skills at IUB.

Stage, Frances K., and Manning, Kathleen. *Enhancing the Multicultural Campus Environment: A Cultural Brokering Approach*. San Francisco: Jossey-Bass Inc., Publishers, 1993, 92 pp., $15.95, paper.

This volume of *New Directions for Student Services* moves forward from a descriptive perspective of what is happening on college campuses. It describes an approach to working with students that involves "cultural brokering," which enjoins us to learn to think contextually, span boundaries, ensure optimum performance, and take action. Stage is Associate Professor of Education and Associate Dean of Research and Development for the School of Education at IUB.

Valdman, Albert. *Bien Entendu! Introduction à la prononciation française*. Englewood Cliffs, New Jersey: Prentice Hall, 1993, 244 pp., $35.33, cloth.

Intended for undergraduate and graduate courses in French phonetics, this book is a complete language package featuring a textbook and recordings that provides a systematic description of French pronunciation along with a series of reinforcement activities and exercises. Valdman is Rudy Professor of French and Linguistics at IUB.

Wysong, Earl. *High Risk and High Stakes: Health Professionals, Politics, and Policy*. Westport, Connecticut: Greenwood Press, 1992, 192 pp., $45.00, cloth.

The author analyzes the nature and extent of the involvement of seven major health and safety professional organizations in the development of the most significant national reform effort in occupational health policy since the OSH Act of 1970: The High Risk Occupational Disease Notification and Prevention Act. He provides an appraisal of the influence of sponsorship, interpenetration, and resource dependency. He concludes that the policy involvement activities of these groups are politically linked to the interests of organizations located in the corporate or public sectors of the economy. Wysong is Assistant Professor of Sociology at IUK.

Early efforts to explore the brain came from the same curiosity that draws scientists today. This Dutch woodcut from J. Dryander's Anatonie *(1537) shows that the brain was already understood at this time as a structure composed of diverse parts.*

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